Seasonal forecasting: supporting marine fishers and managers in a changing climate

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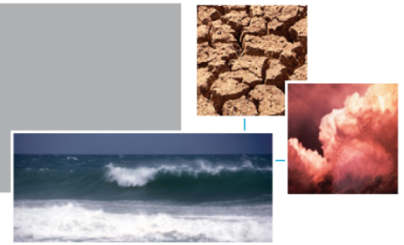
Jason Hartog
Claire Spillman (BOM)

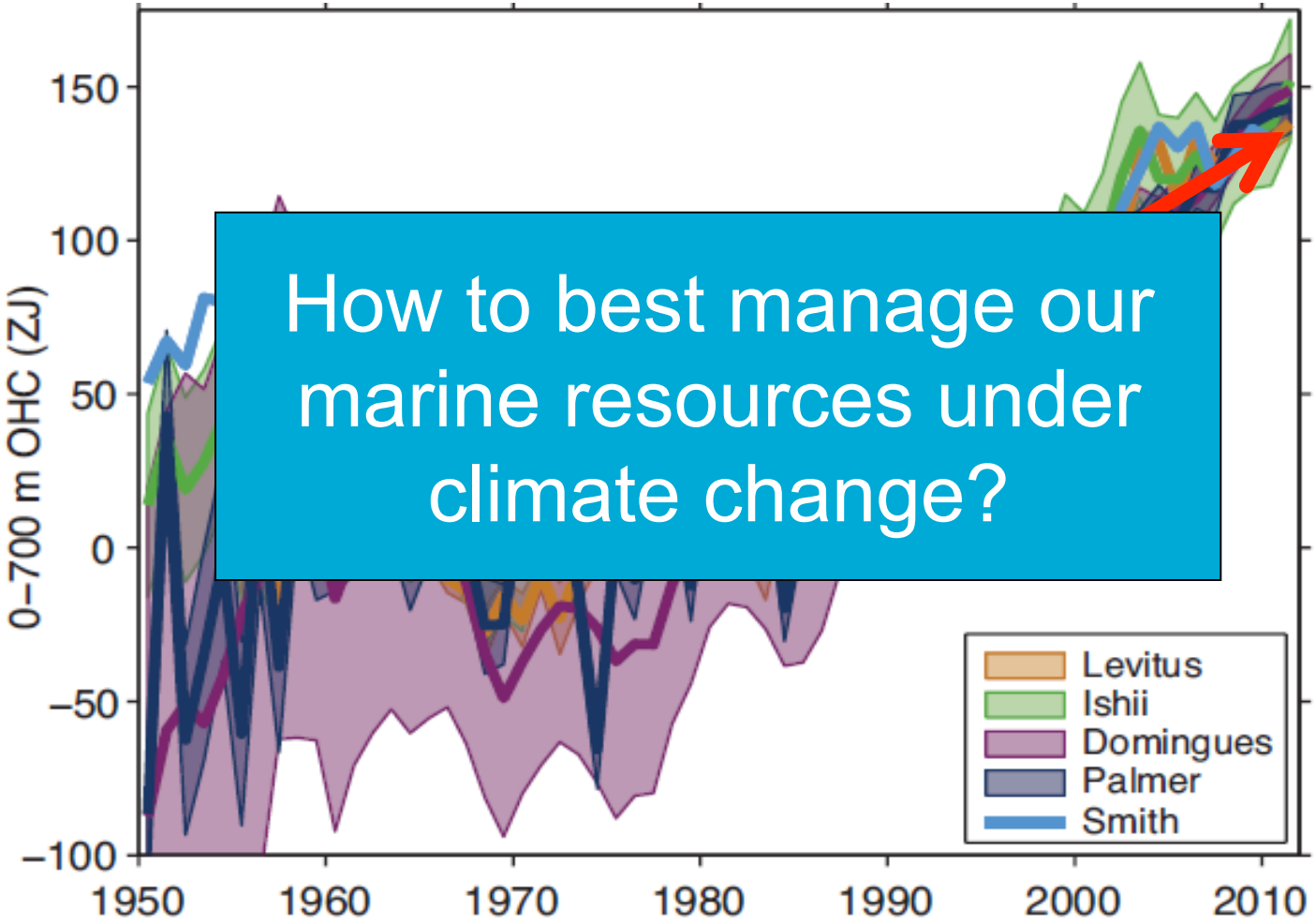
Why has seasonal forecasting worked?

- Pre-conditioning
  - Novel conditions (sometimes a shock)
  - Dynamic realtime habitat forecasting (since 2003)
  - Mature forecast model (POAMA)
- Project team
  - Trust and knowledge in domain
    - Decision context is clear
  - Partnership with BOM
  - End user engagement

Warming oceans



Observation-based estimates of annual global mean upper ocean heat content

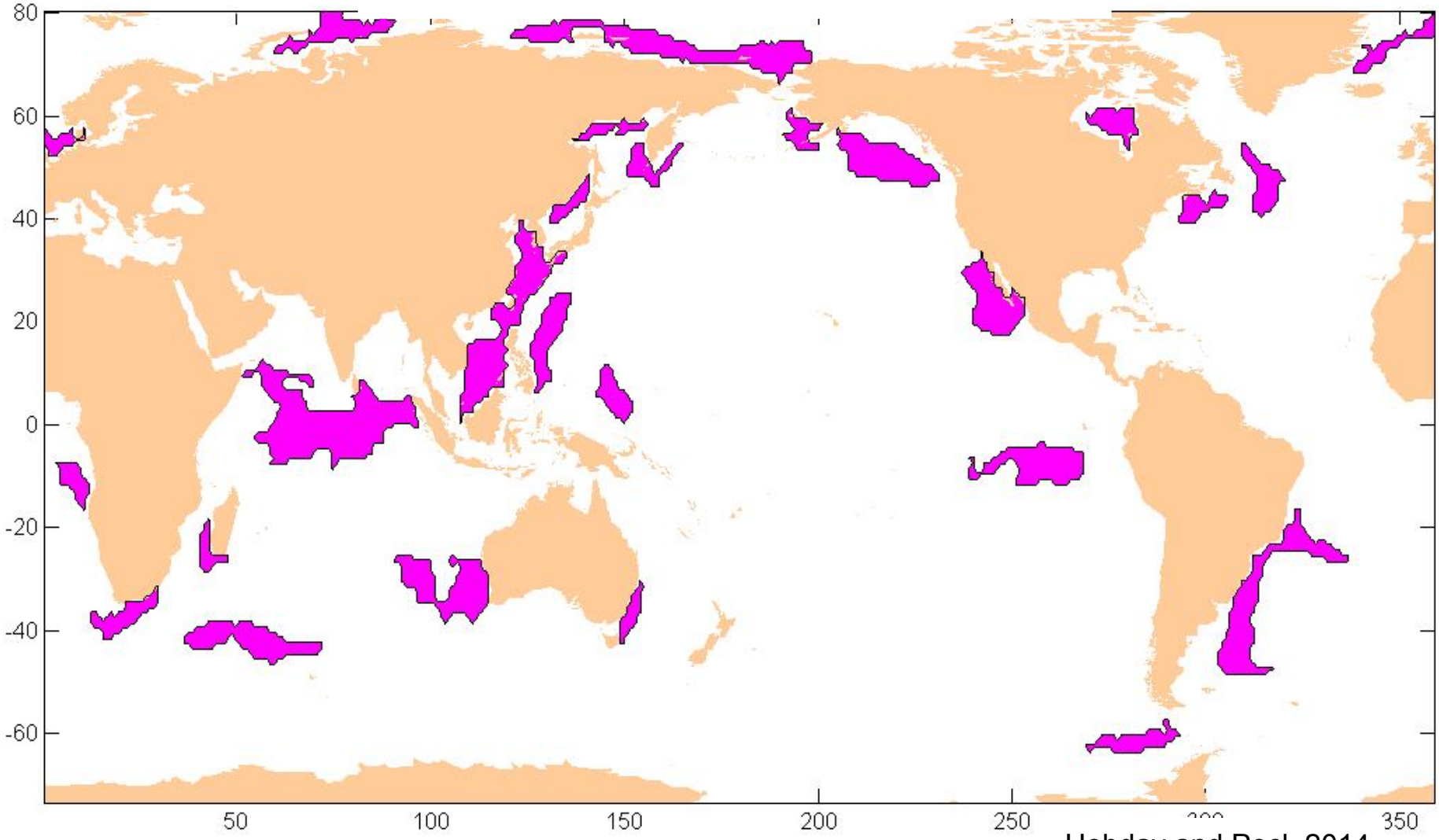


How to best manage our marine resources under climate change?

Fig 3.2 in Rhein et al 2013. Climate Change 2013: The Physical Science Basis. WG1 IPCC AR5

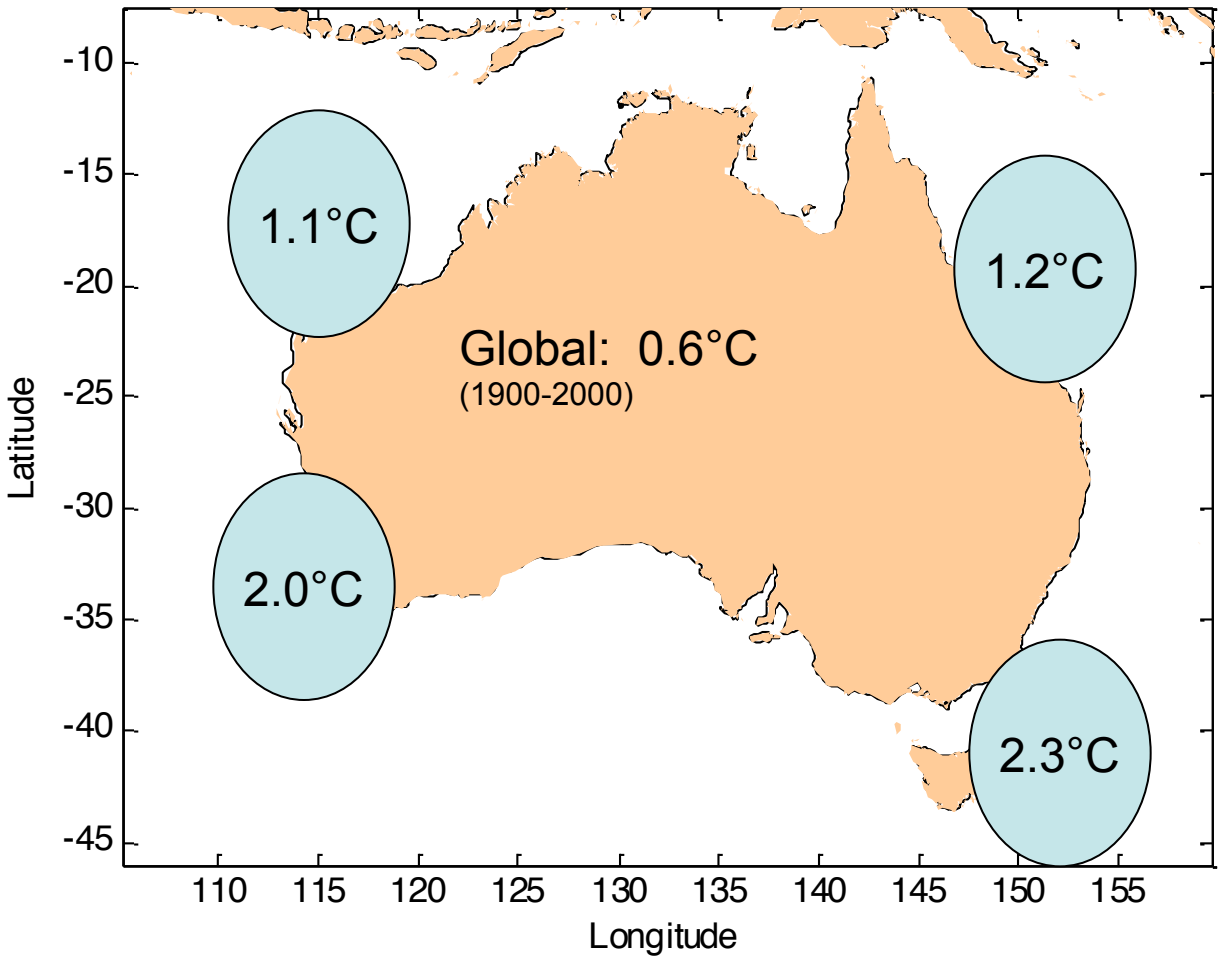
Global marine hotspots

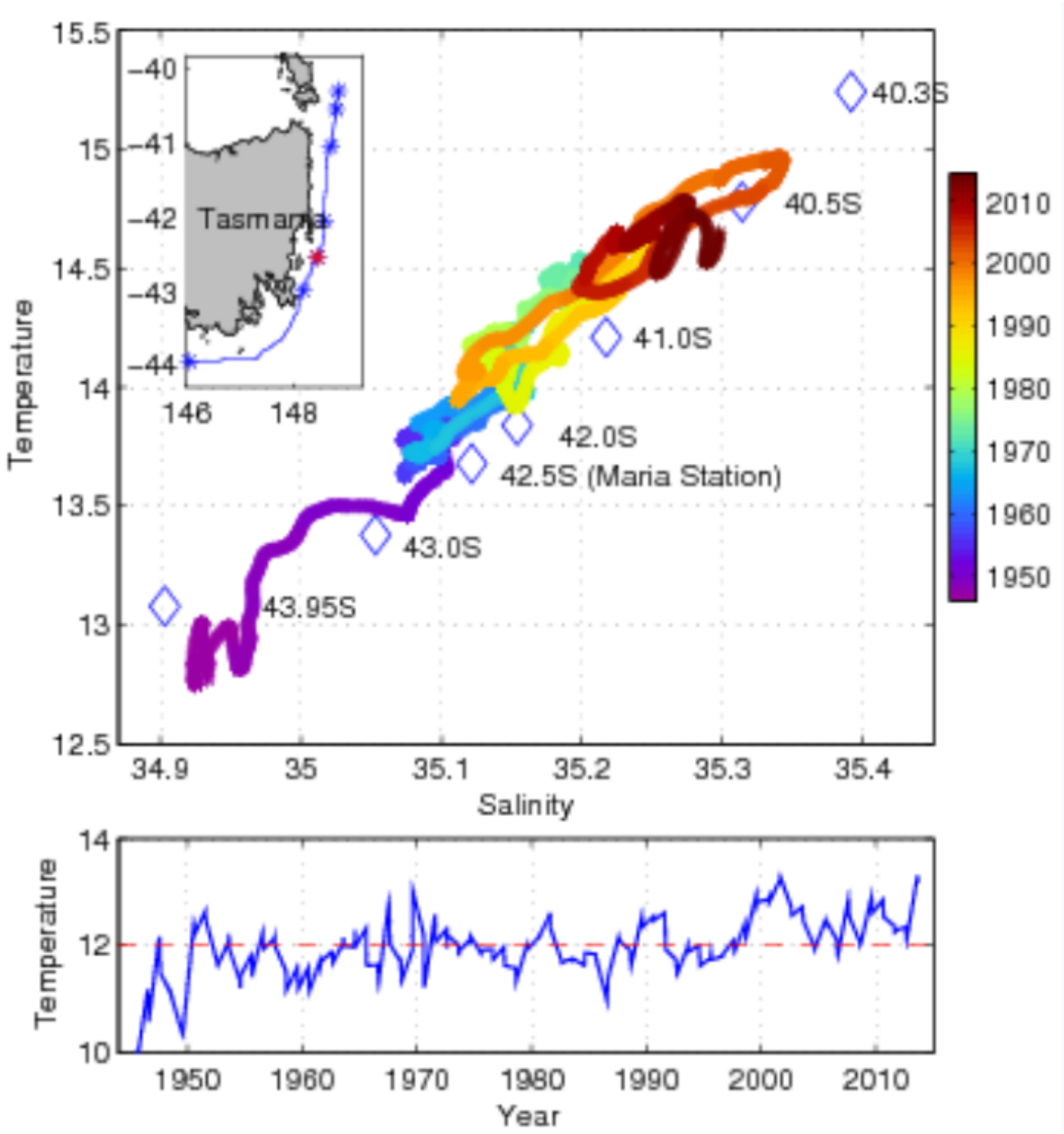
areas of rapid temperature change - www.marinehotspots.org/



Hobday and Pecl, 2014

Observed ocean warming around Australia

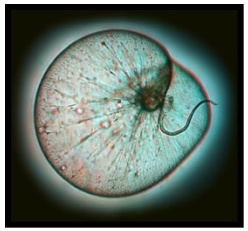



15.5
15
14.5
14
13.5
13
12.5
Temperature
34.9
35
35.1
35.2
35.3
35.4
Salinity
−40
−41
−42
−43
−44
146
148
Tasmania
40.3S
40.5S
41.0S
42.0S
42.5S (Maria Station)
43.0S
43.95S
2010
2000
1990
1980
1970
1960
1950
14
12
10
Temperature
1950
1960
1970
1980
1990
2000
2010
Year

Impact studies - Biological changes in SE – now well documented

14/29 intertidal species have moved further south in Tasmania over last 50 years *(Pitt et al 2010)*

Expansion of sea urchins native to NSW causing loss of kelp forests in Tasmania *(Ling et al 2009)*



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Some
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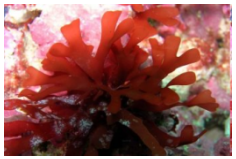
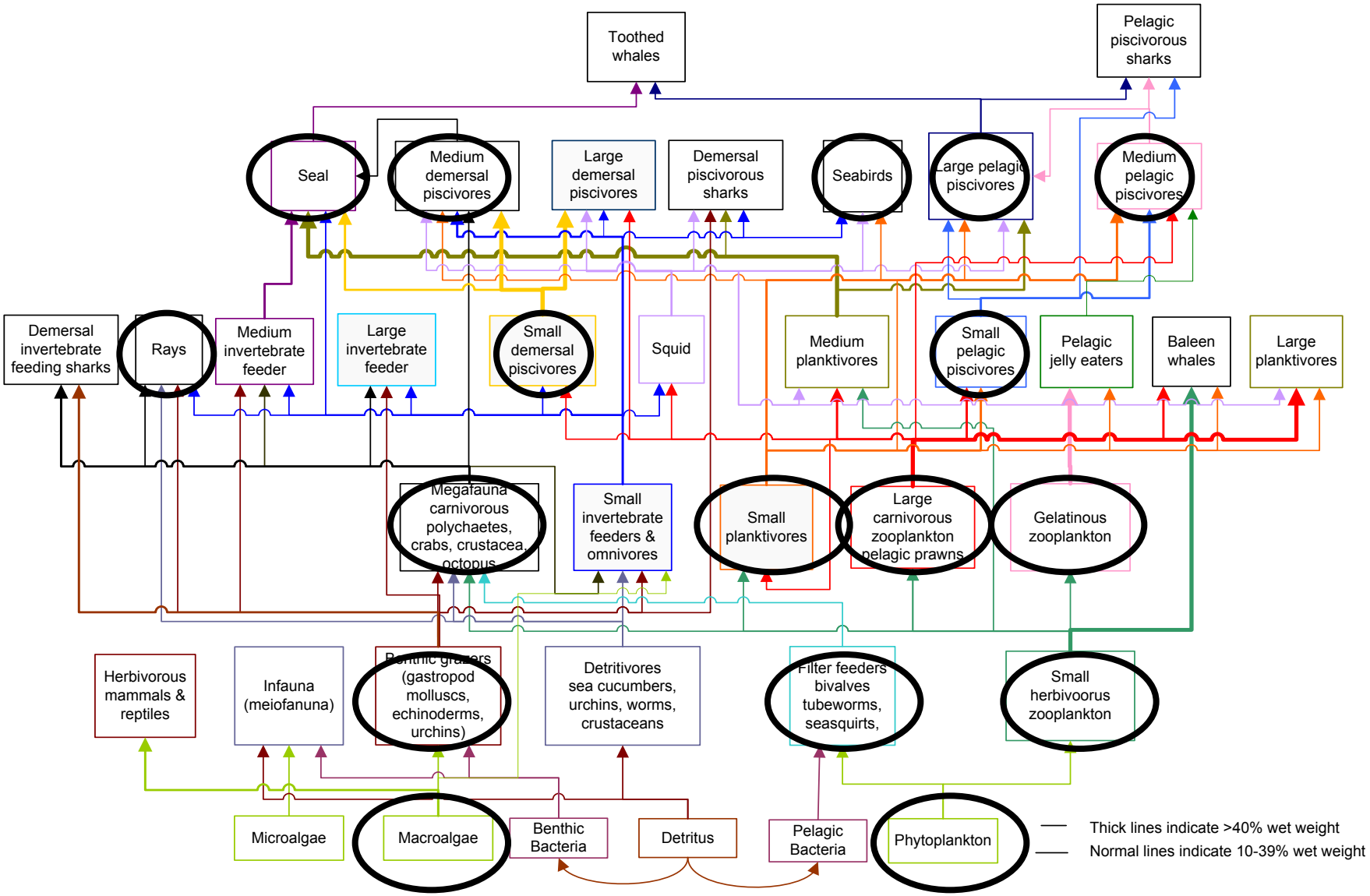
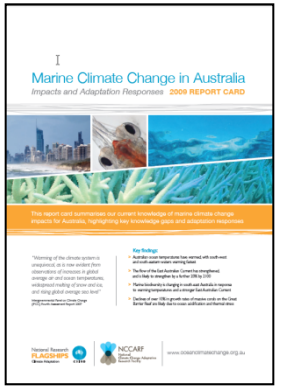


Observed changes in south-east Australia



Frusher et al 2014

2nd Marine Report Card



- Physical
  - Temperature
  - Sea Level
  - East Australia Current
  - Leeuwin Current
  - ENSO
  - Ocean Acidification
- Biological
  - Microbes
  - Algae
  - Seagrass
  - Mangroves and tidal wetlands
  - Phytoplankton
  - Zooplankton
  - Pelagic fish
  - Coral reefs
  - Tropical fish
  - Temperate fish
  - Marine reptiles
  - Seabirds
  - Marine Mammals

http://www.oceanclimatechange.org.au

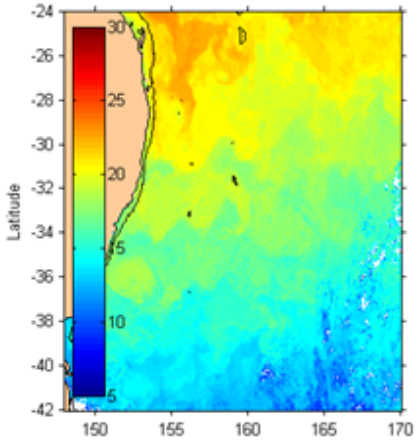
Pelagic Habitat Changes

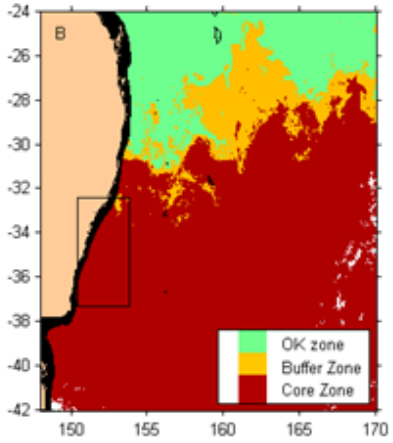
Sea SurfaceT

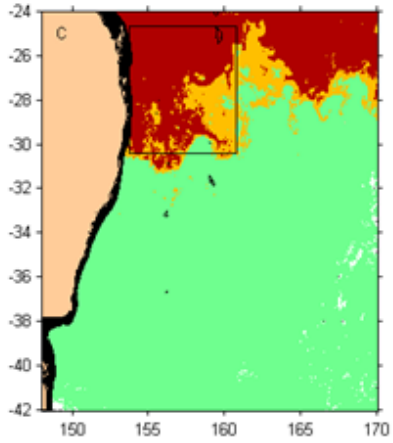
SBT

YFT

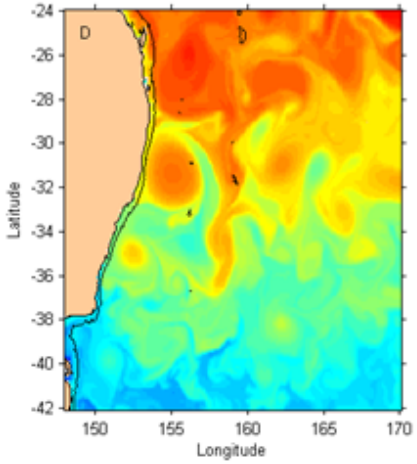
August 2008

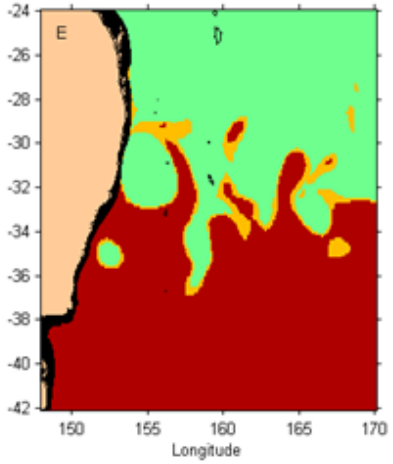


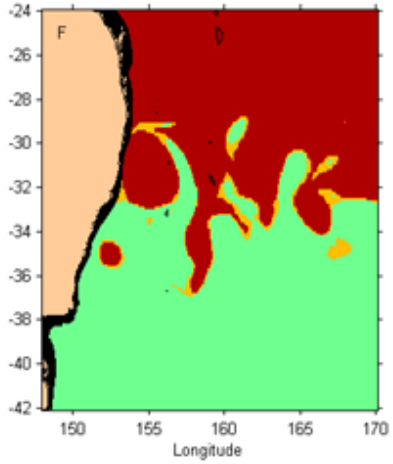




August 2064



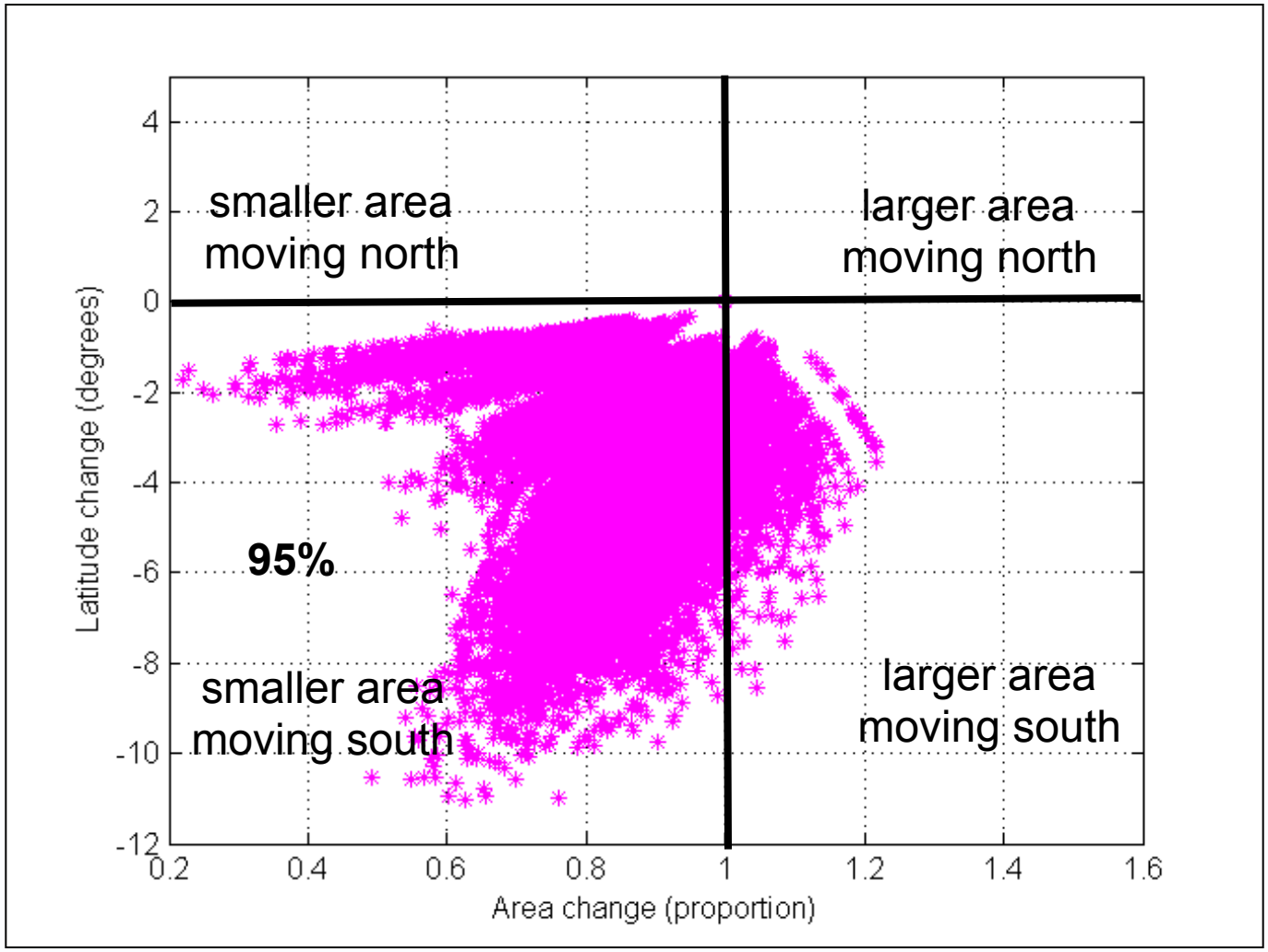




Hartog et al. (2011)

Overall change in resource/species distribution

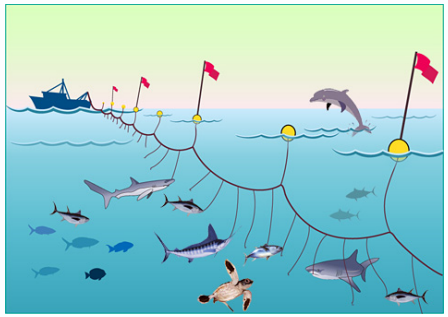
(14 species, 12 months, 9 models, 25 scenarios = 37,800 futures)

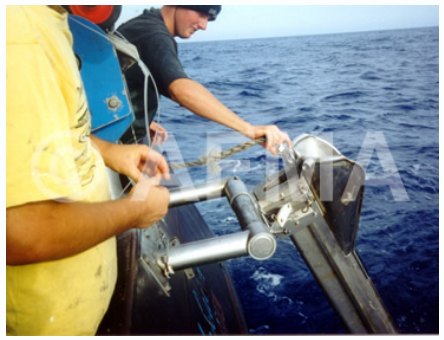


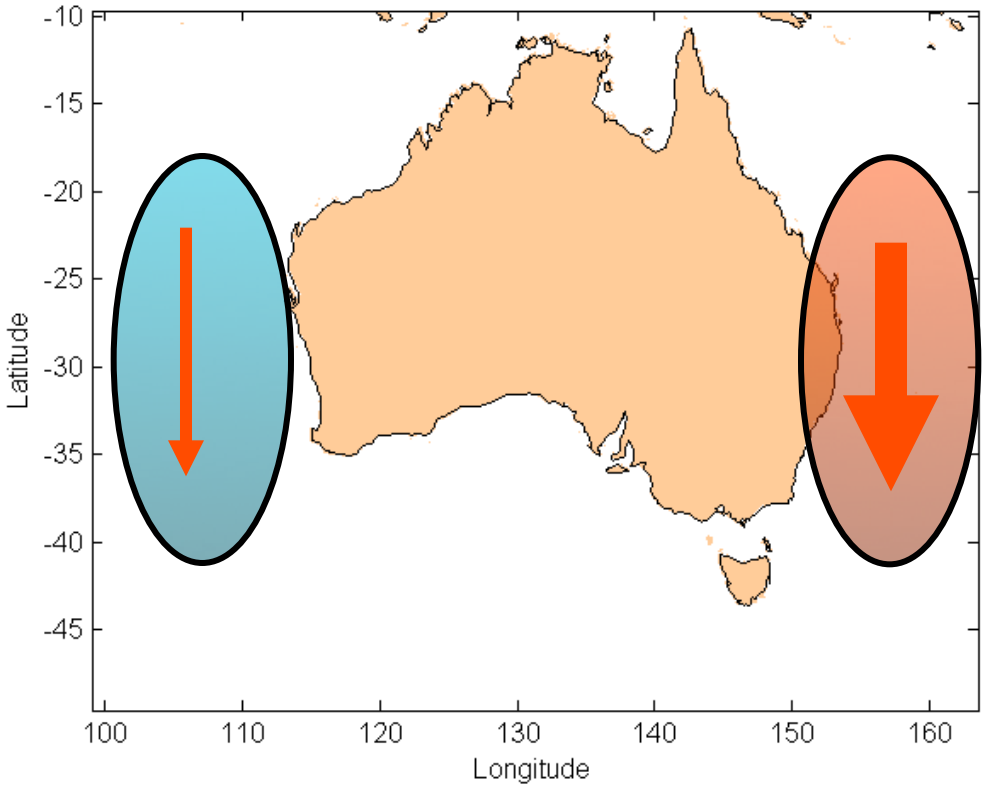
Hobday (2010)

Projected biological changes (e.g. distribution)

11 species in Australian longline fisheries





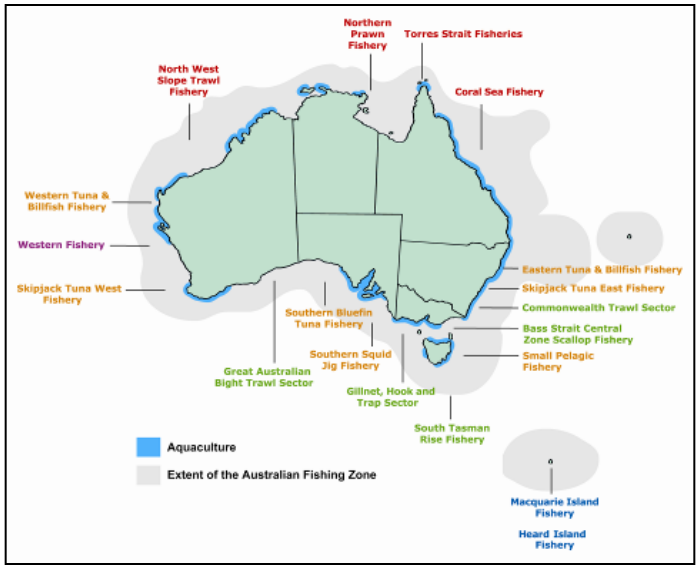


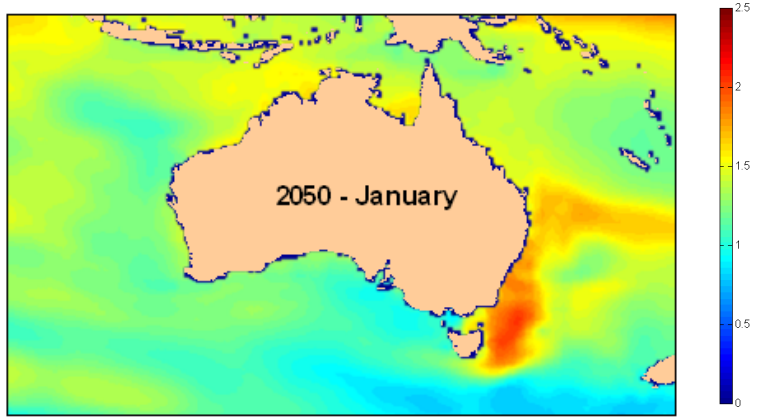
Hobday (2010)

Long-term climate risk to seafood sector

Biophysical impacts include:

- Range changes (best location)
  - Species move south (east coast) (+ / -)
- Growth changes
  - ↑ growth and recruitment (prawns)
  - Fish growth rates
- Environmental changes
  - ↑ upwelling (↑ productivity?)
  - Disease risk
- Extreme events
  - ↑ storms (freshwater, turbidity)

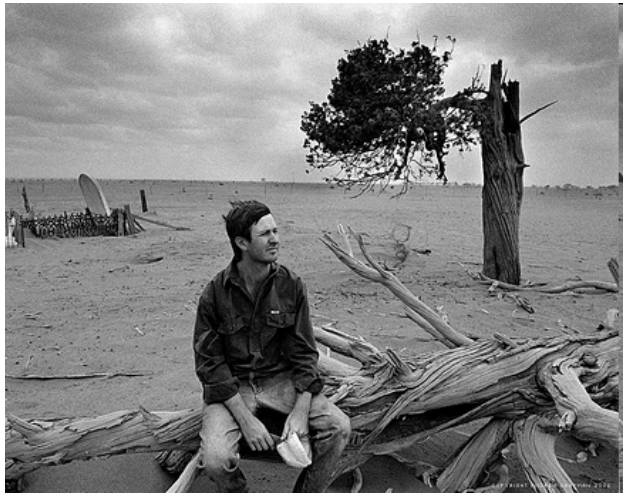




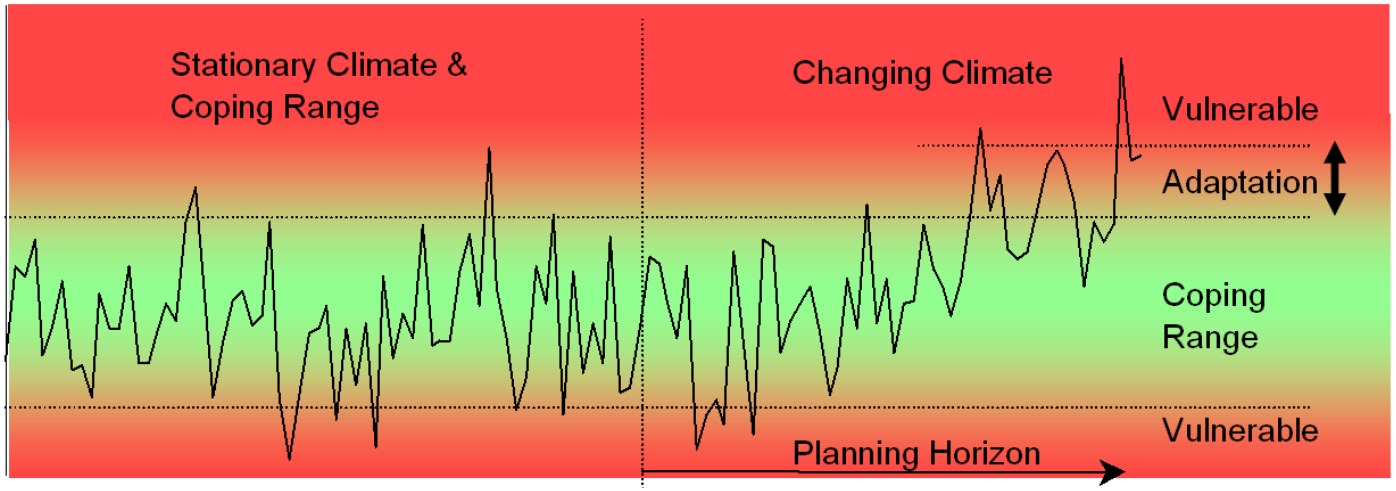
Hobday and Lough 2011

Preliminary Assessment of Climate Change Impacts for Australian Fisheries & Aquaculture (Hobday et al 2008)

Humans think they are resilient….



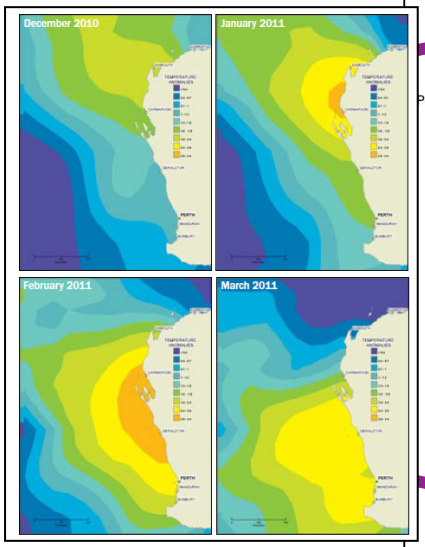
"We have always adapted to changes in the past"

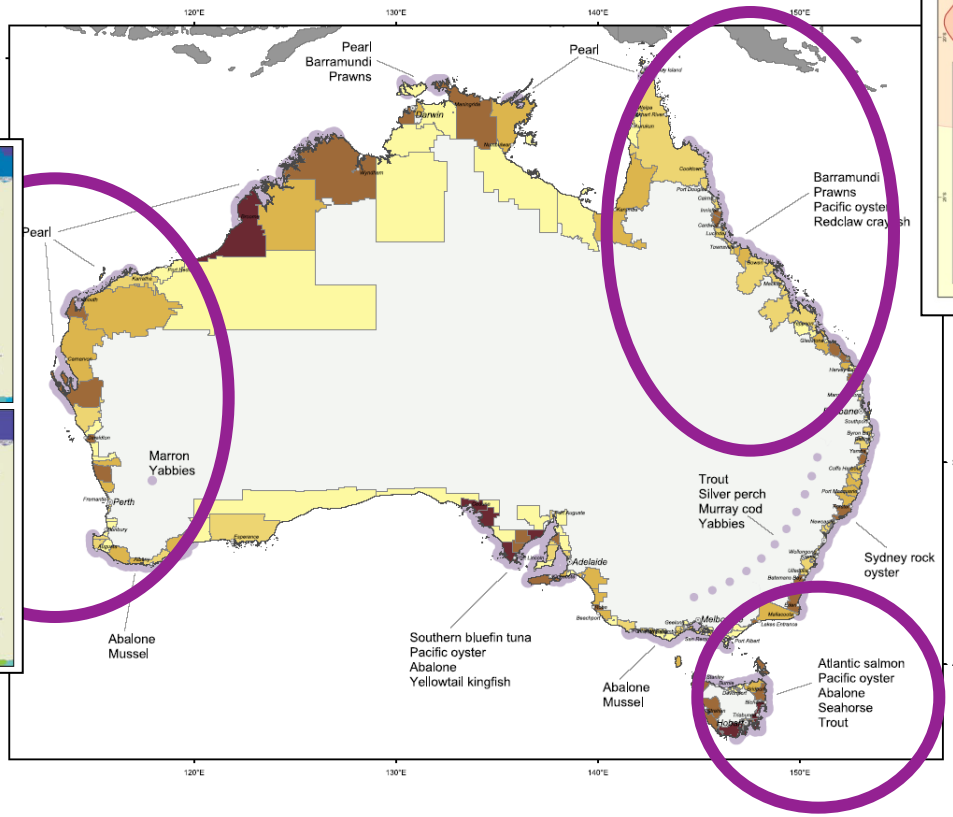


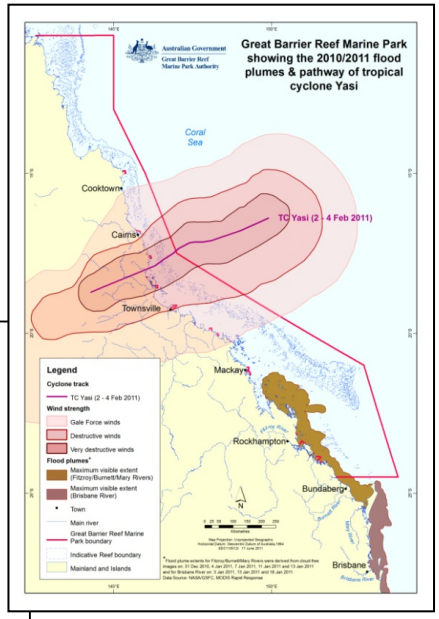
Jones & Mearns 2005

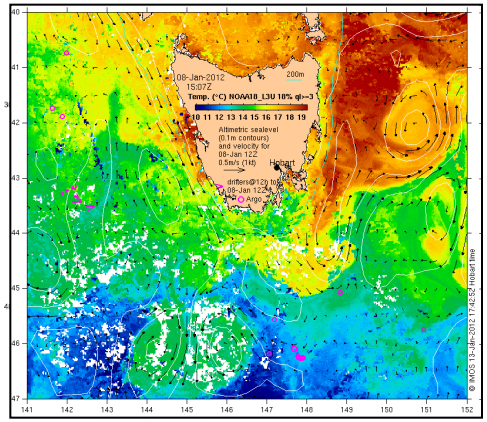
Recent extremes suggest otherwise

- Marine heat wave - Western Australia 2011
- Flooding and cyclone - Queensland 2011
- Abnormally warm summer - Tasmania 2012









Hodgkinson et al 2014

The future will be different…

- Climate change is leading to a future where past experience is of reduced value.
- Past patterns will not be repeated: novel combinations of physics, chemistry, and biology
- Need to make decisions that are generally ok even if the details change, based on the best information available at the time
- Risk management approach

Climate variability vs. climate change

In fisheries and aquaculture, coping with climate variability is "business as usual" to many…

- Coping with climate variability is **responsive** adaptation

  Cost effective? Does it allow for "opportunity" to be recognised?

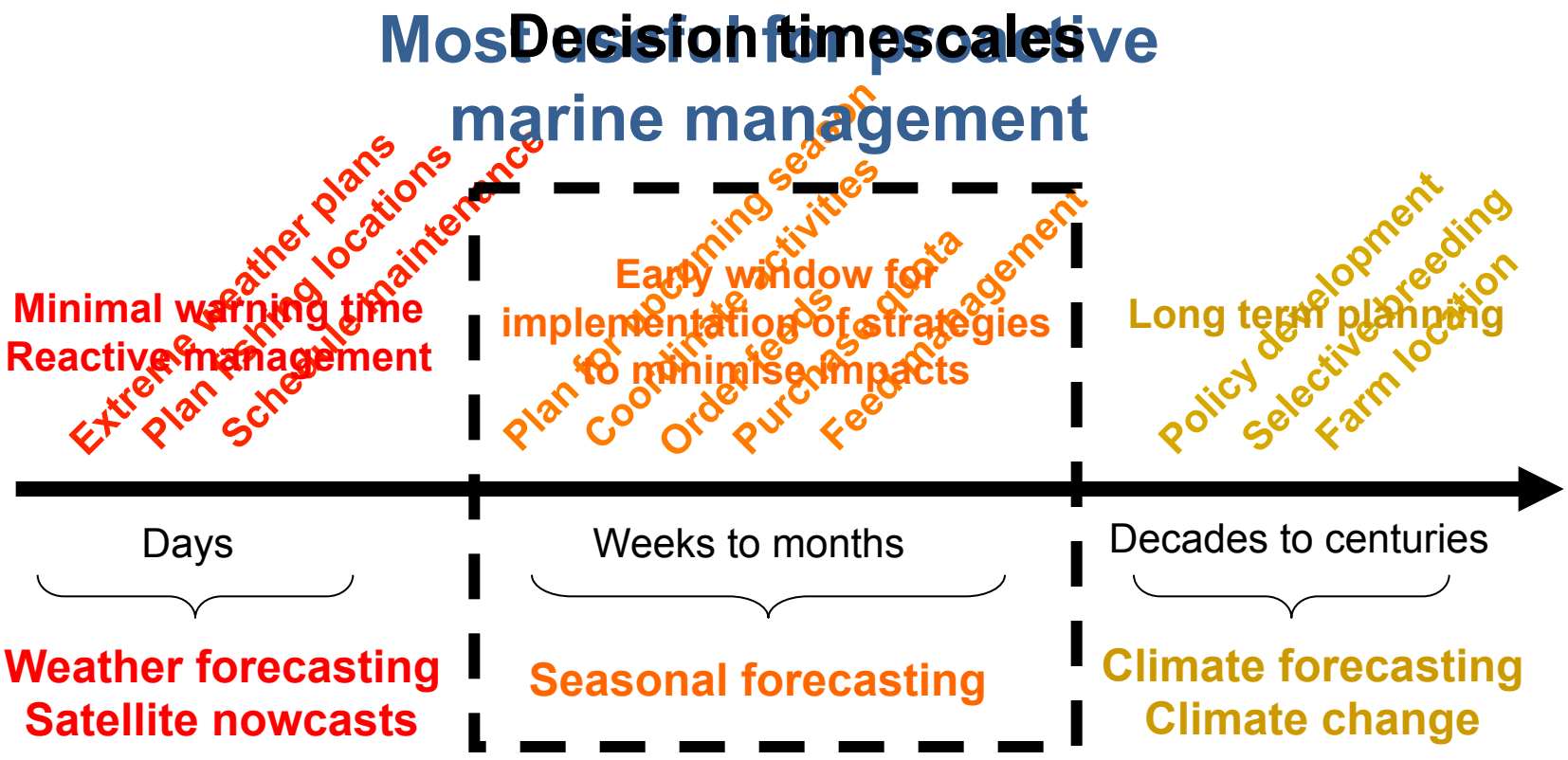
- Climate change is a new factor for a range of businesses

  Can it just be managed as for climate variability?

➡ Anticipating climate variability & change is **proactive** adaptation

➡ Business performance could be improved with predictions about the future

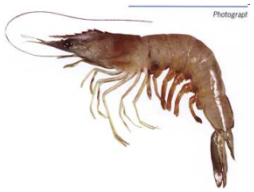
Recognize relevant time scales

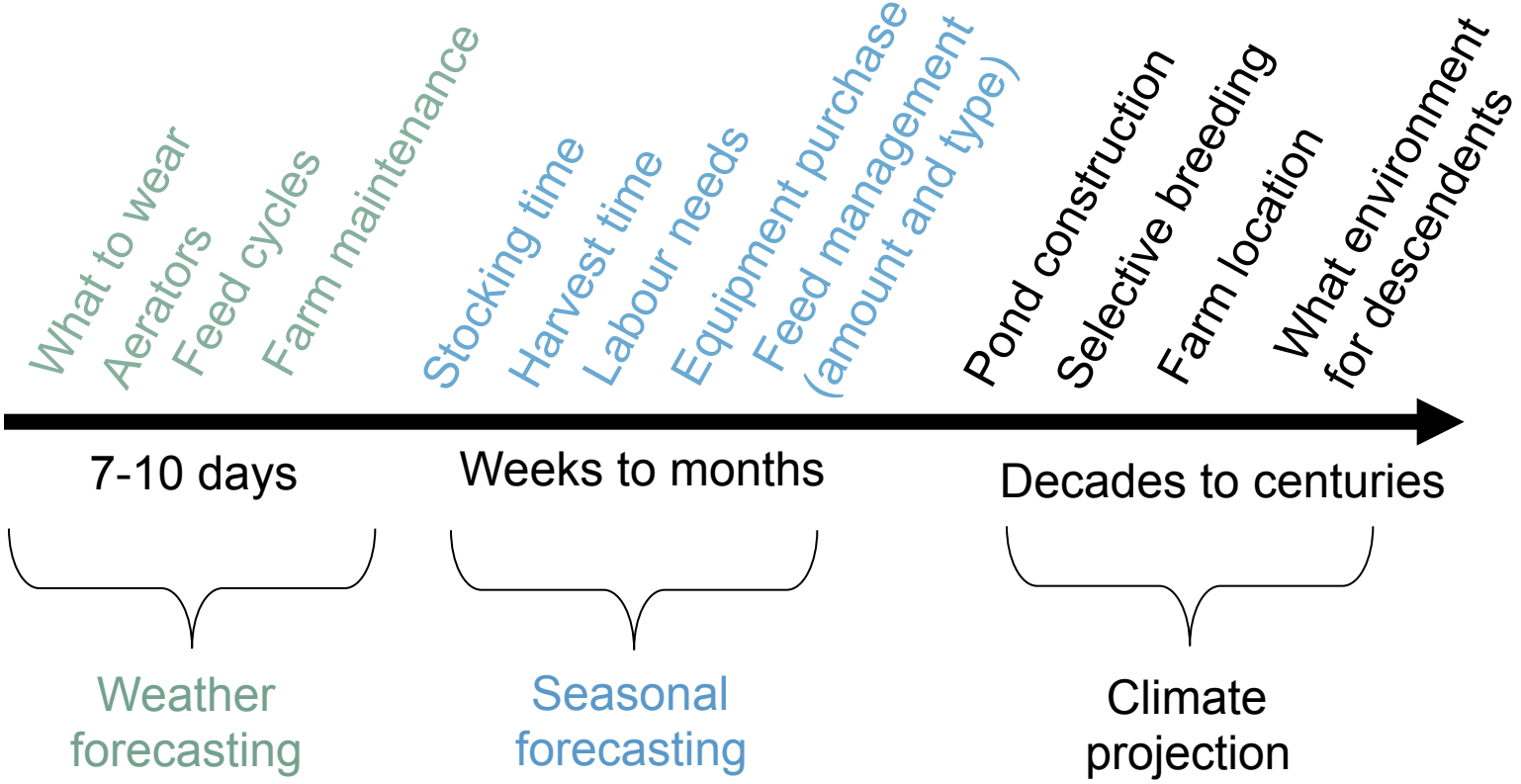


Better managed marine resources have improved resilience under climate change

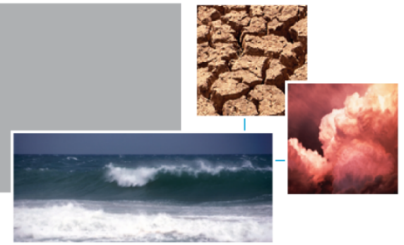
Hobday et al, in press

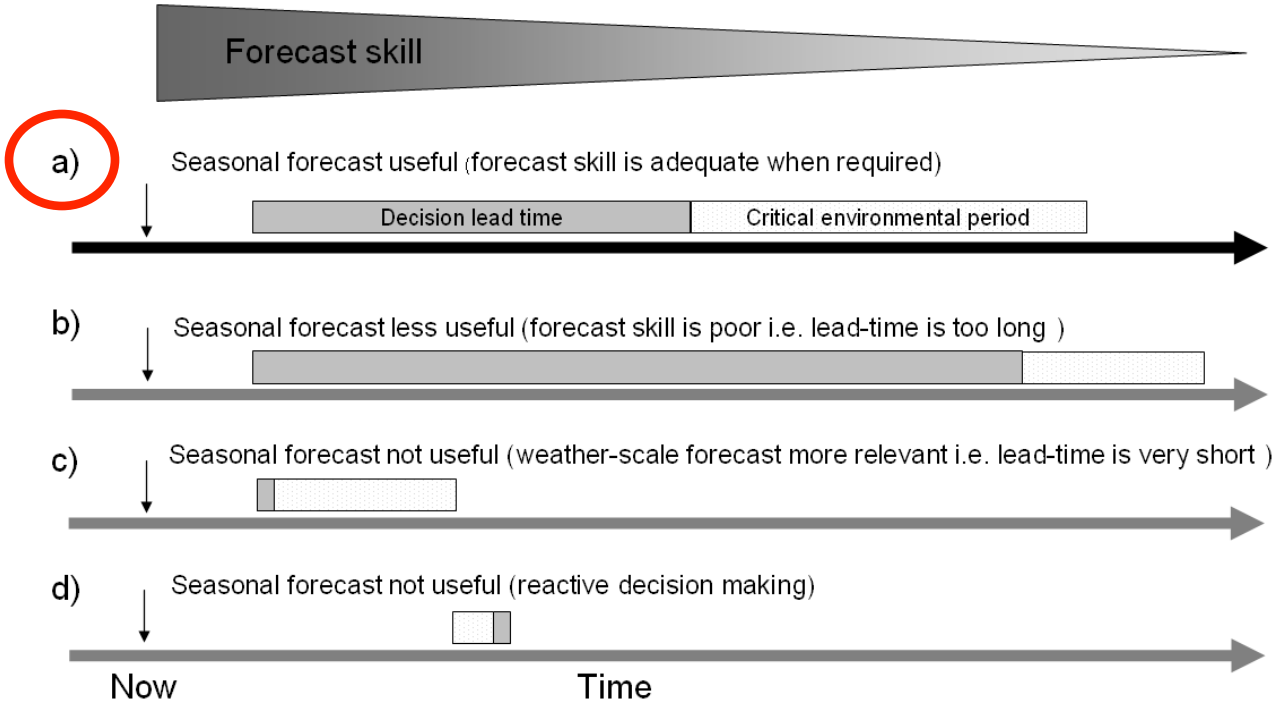
Recognize relevant time scales





When is seasonal forecasting useful?





Usefulness depends on the timing of both the **management decision** to be made and that of the **critical environmental period** affecting the decision, together with **forecast accuracy** at that time.

When the lead-time required to make a decision is such that the forecast skill for the critical environmental period is adequate, a seasonal forecast may be useful (a).

Australian Government
Bureau of Meteorology

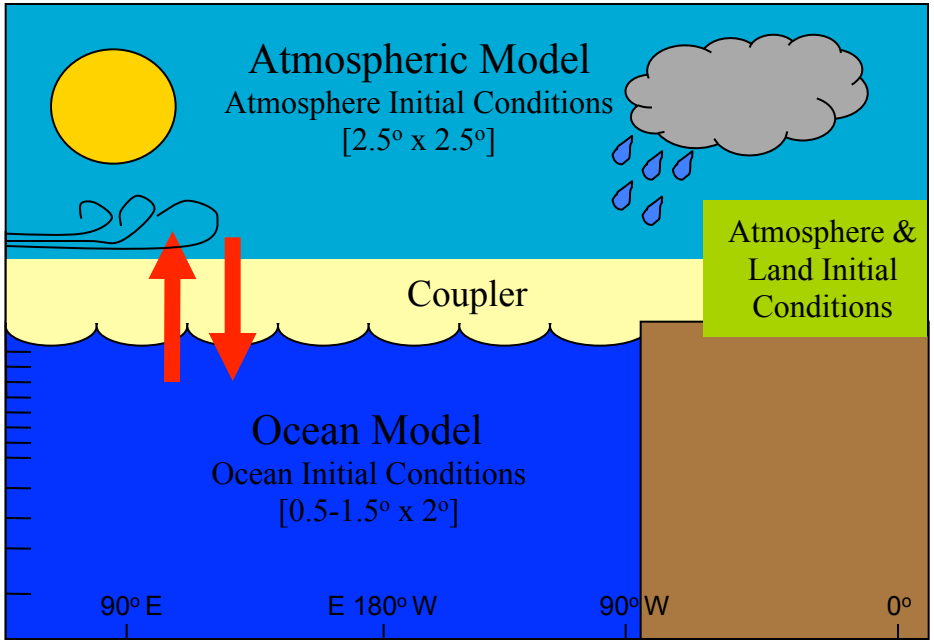
Hobday et al in press

CSIRO

Seasonal forecasting

Predictive **O**cean **A**tmosphere **M**odel for **A**ustralia

Global dynamical coupled ensemble ocean-atmosphere and data assimilation seasonal prediction system



- Forecasts out to 9 months
- Weekly to seasonal multi-model predictions
- Ocean and atmosphere products available
- 33 member ensemble
- Probabilistic forecasts
- Run operationally x2 weekly

http://poama.bom.gov.au

Spillman & Alves 2009, Spillman 2011, Hudson et al 2013

Australian Government
Bureau of Meteorology

CSIRO

POAMA applications




Commercial wild fisheries

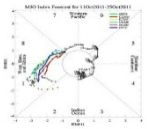

Aquaculture

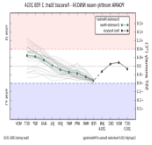

Sea level extremes

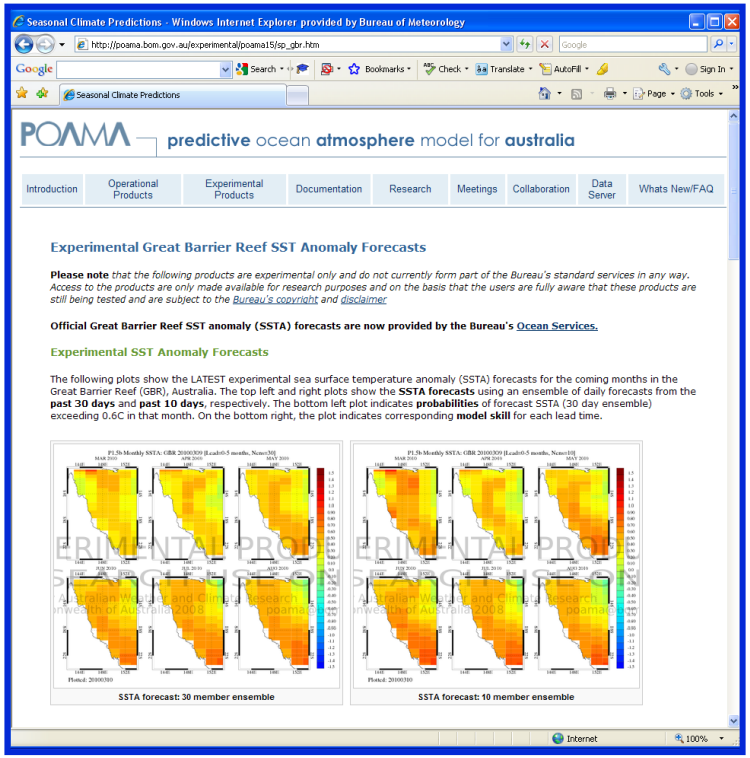

Coral bleaching risk


Heatwaves


Wet season onset


Madden-Julian Oscillation


ENSO



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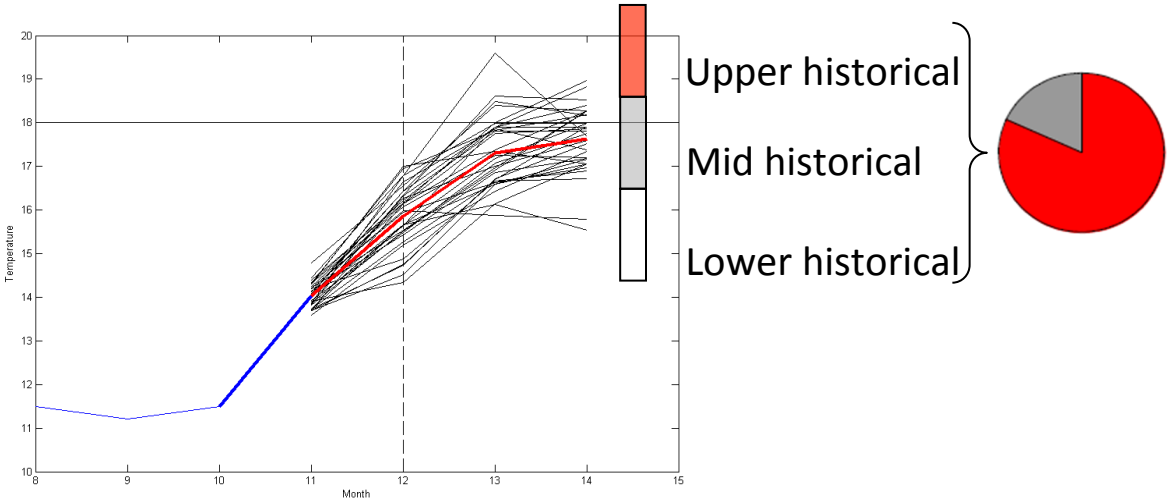
Ensemble prediction

- Gives the likelihood of an event occurring
- Ensembles give the range of possibilities & degree of uncertainty
- Cost/benefit analyses
- Perturb the initial state within its estimated error to see impact of possible errors



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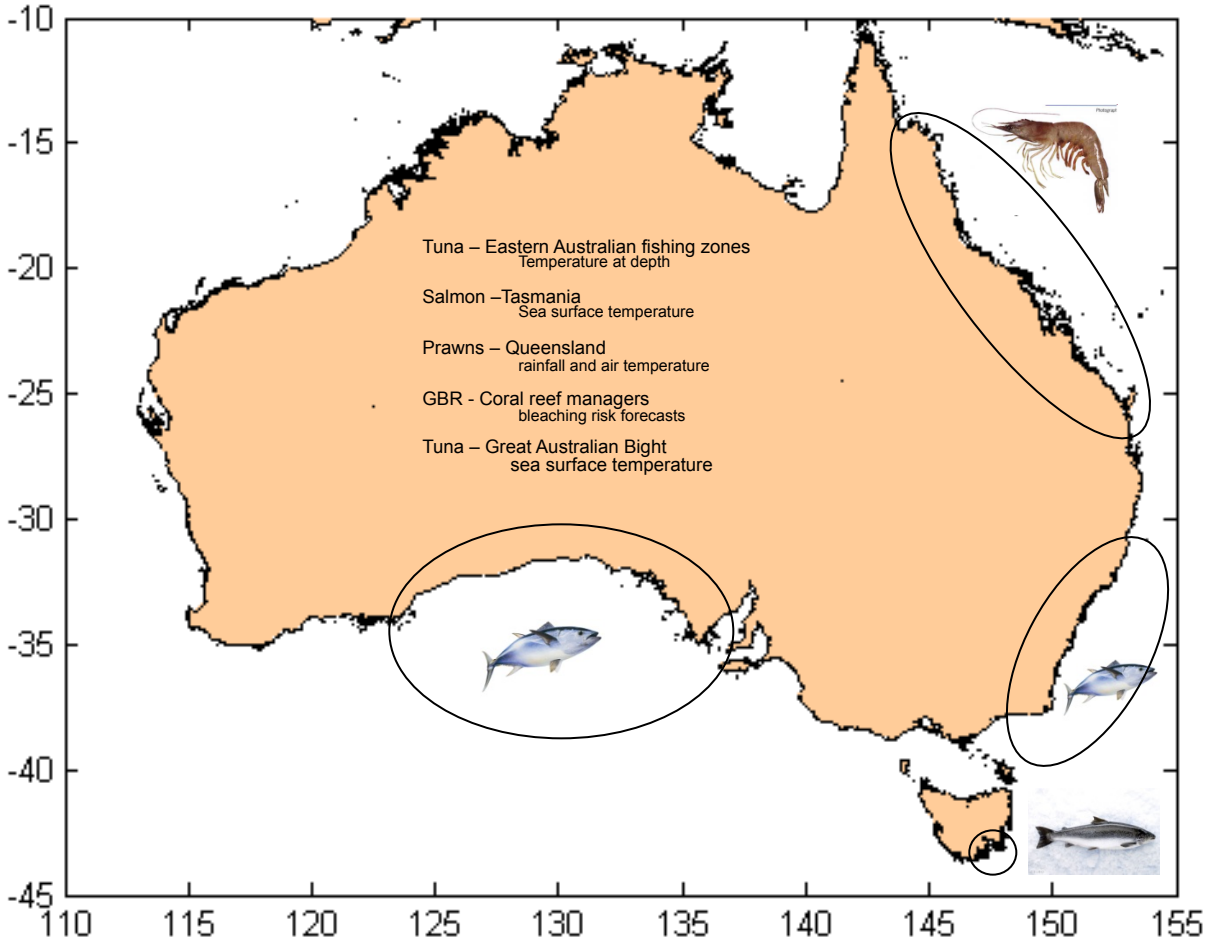
Fisheries and aquaculture seasonal forecasts

(primary variable & “habitat”)



Development stages - forecast



A. Assess needs

Define management or industry need

Determine critical variables & decision timescales

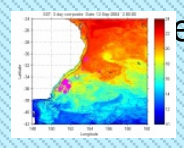
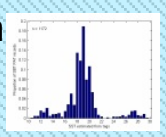
Verification data

B. Development

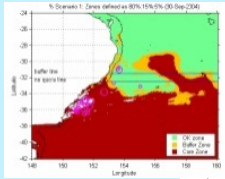
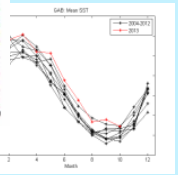
Assess skill using POAMA hindcast

Produce habitat distribution

eca +

Forecast products

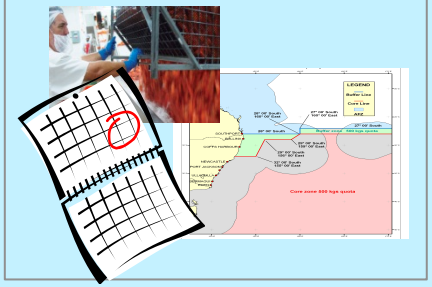



C. Implementation

Forecast delivery

Support & education

End user decision



User feedback

Australian Government
Bureau of Meteorology

Hobday et al in press

CSIRO

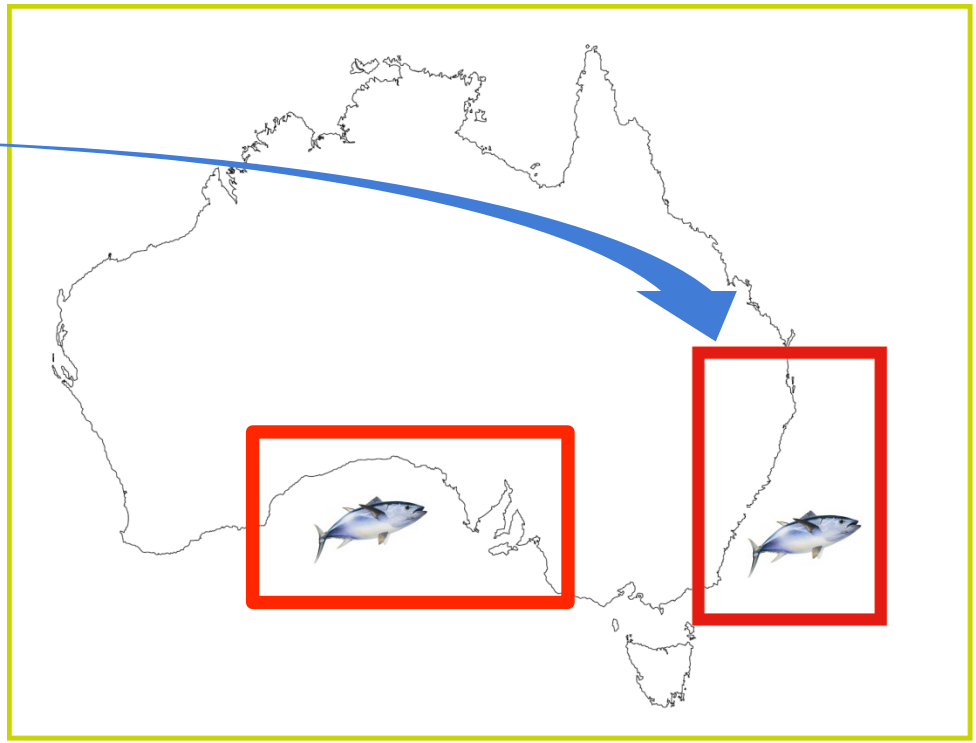
1. Southern bluefin tuna fisheries

Management issue:
Quota managed species

Management need:
Reduce non-quota capture

Management solution:
Spatial zoning to regulate fisher access

Management support:
Seasonal forecasts to assist future planning of zones



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Real time habitat “prediction” (since 2003)

Reduce bycatch of SBT

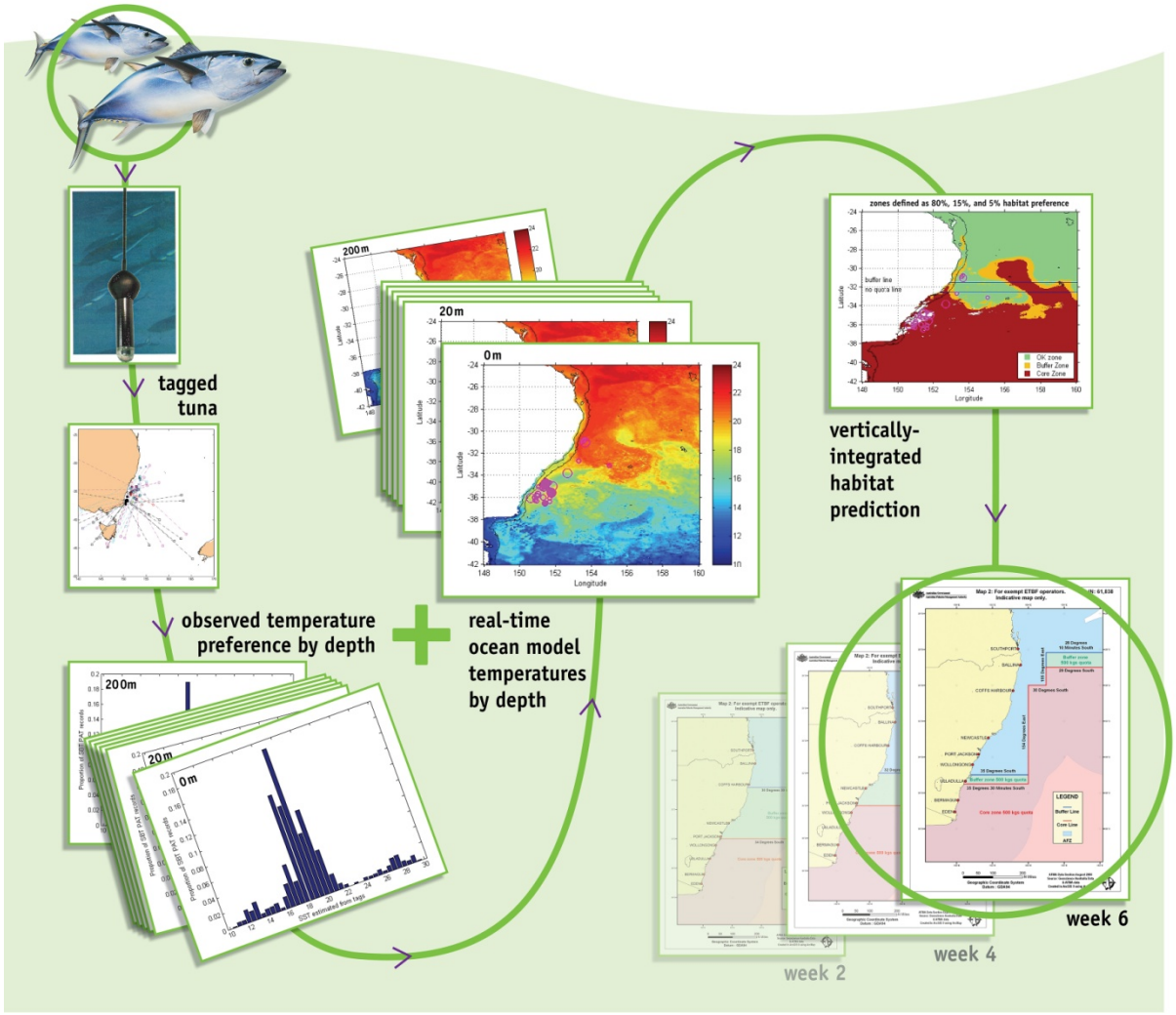
Three zones based on the expected distribution of SBT.

Report sent to fisheries management on a fortnightly basis

<u>Action</u>

AFMA regulates spatial access of long line vessels to the fishery based on quota holdings.

Observers required in the core zone.

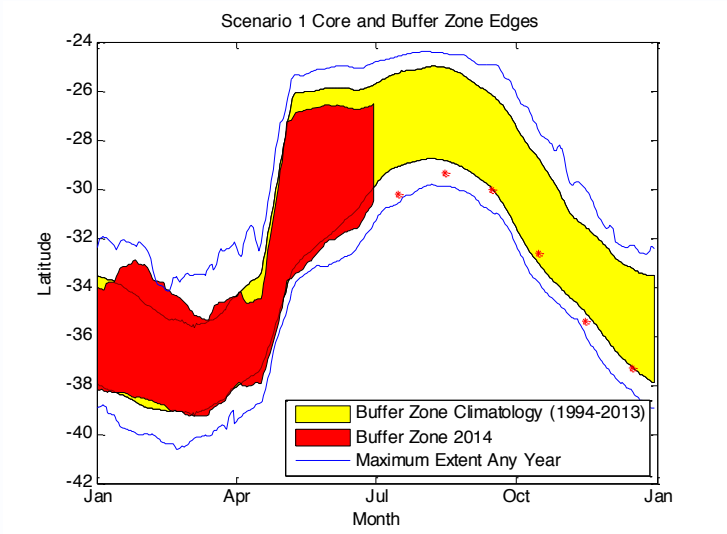


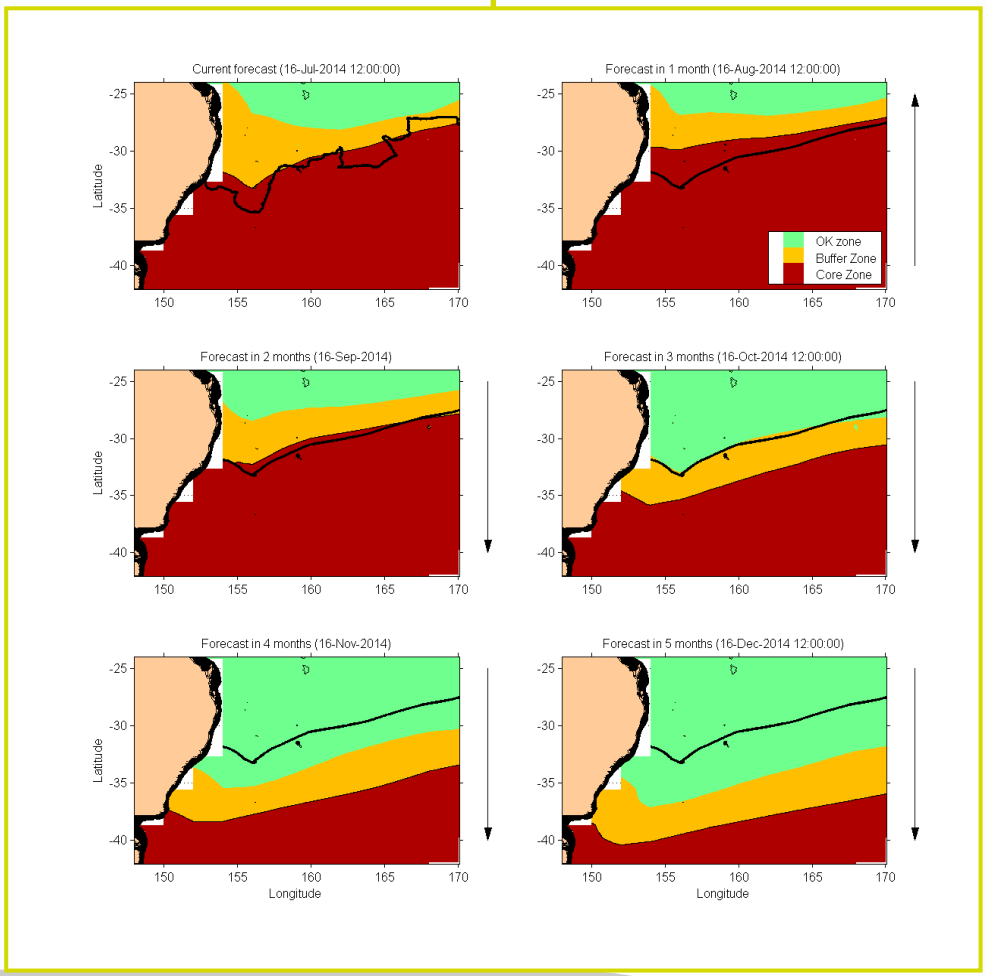
Hobday and Hartmann 2006; Hartog and Hobday (in press)

Seasonal Habitat Prediction

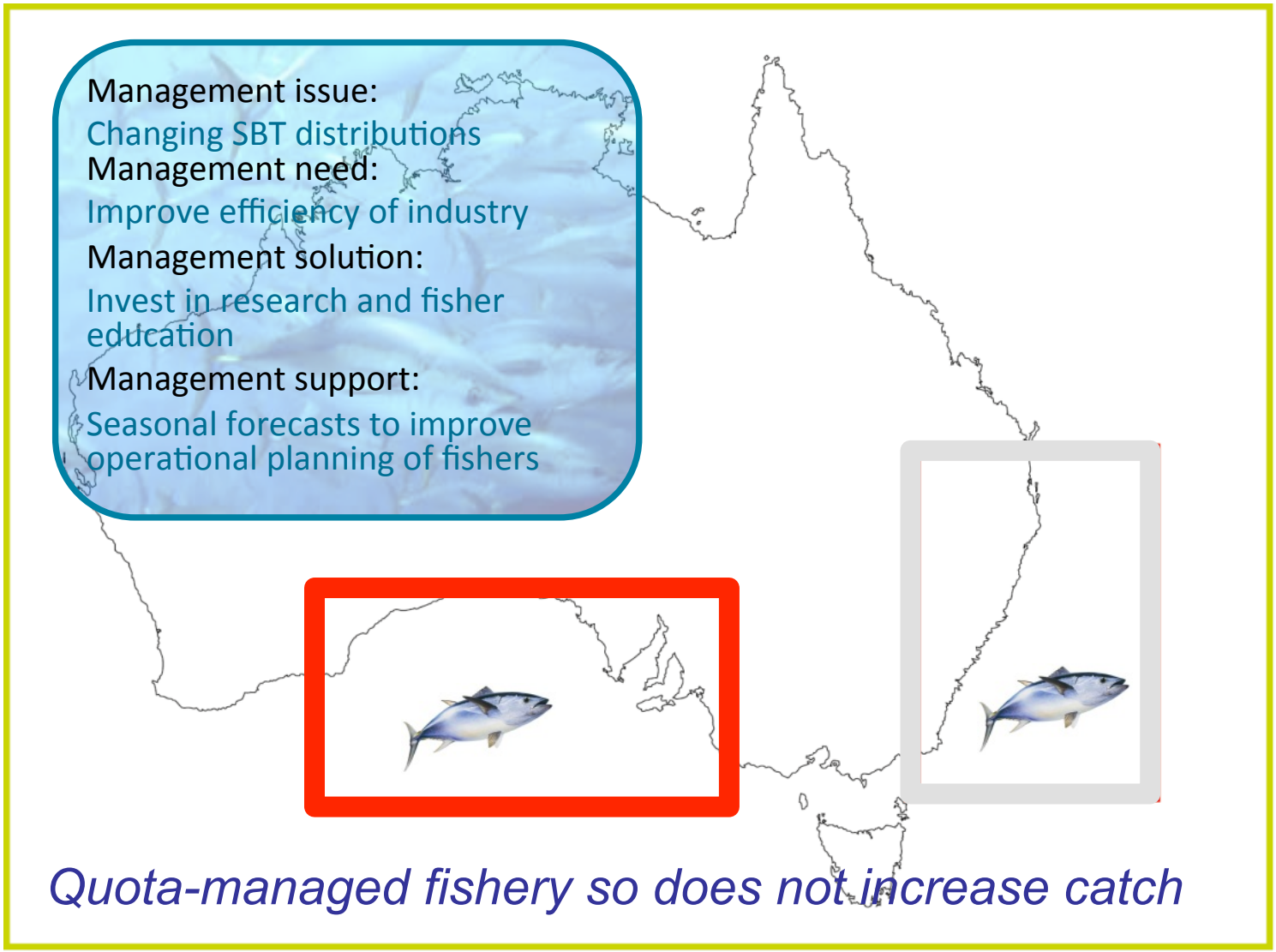
- Seasonal forecasts from a coupled ocean-atmosphere model (POAMA) have been added to our habitat model, allowing predictions of SBT habitat out to 5 months.

- This seasonal forecasting offers both managers and fishers the potential to plan for upcoming restrictions, and strategically modify their fishing activities.

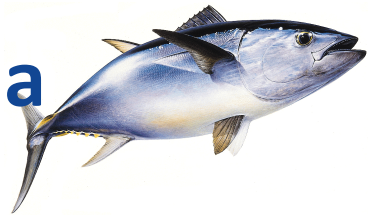




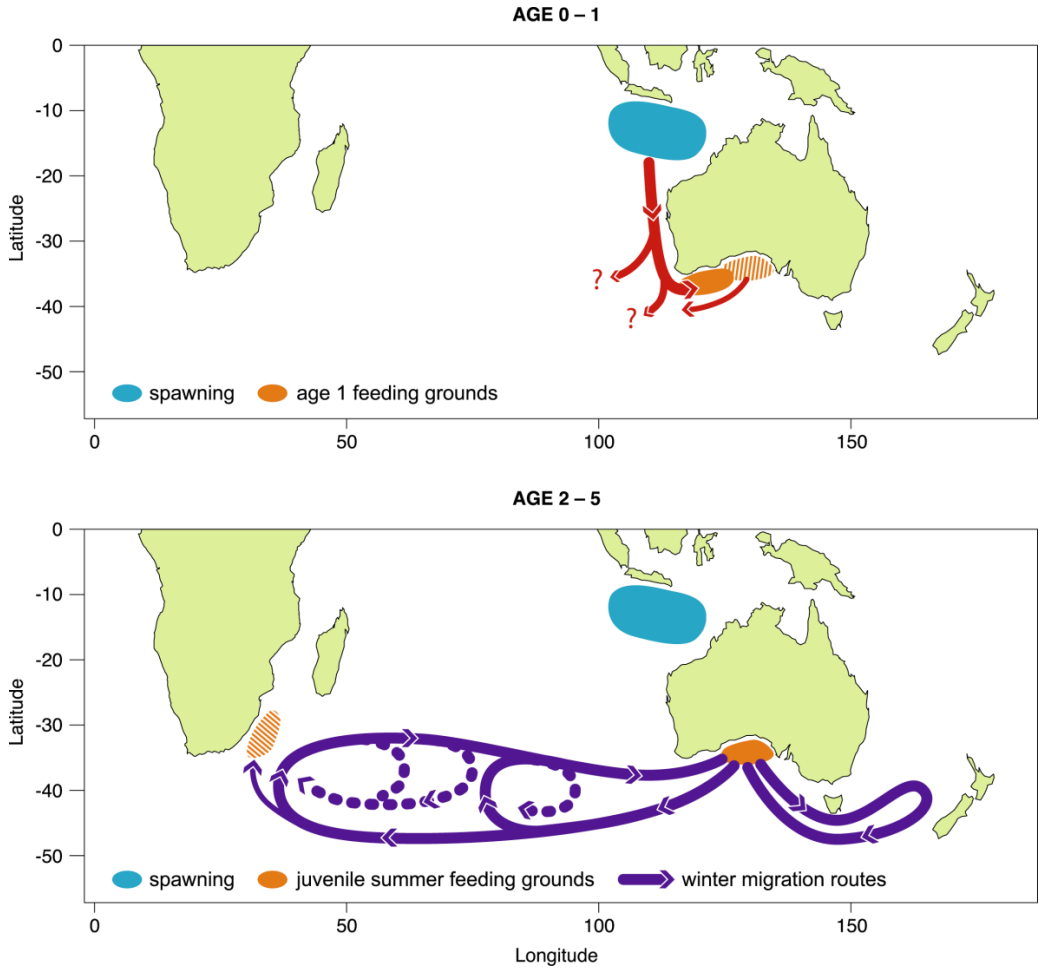
Southern bluefin tuna fishery example #2



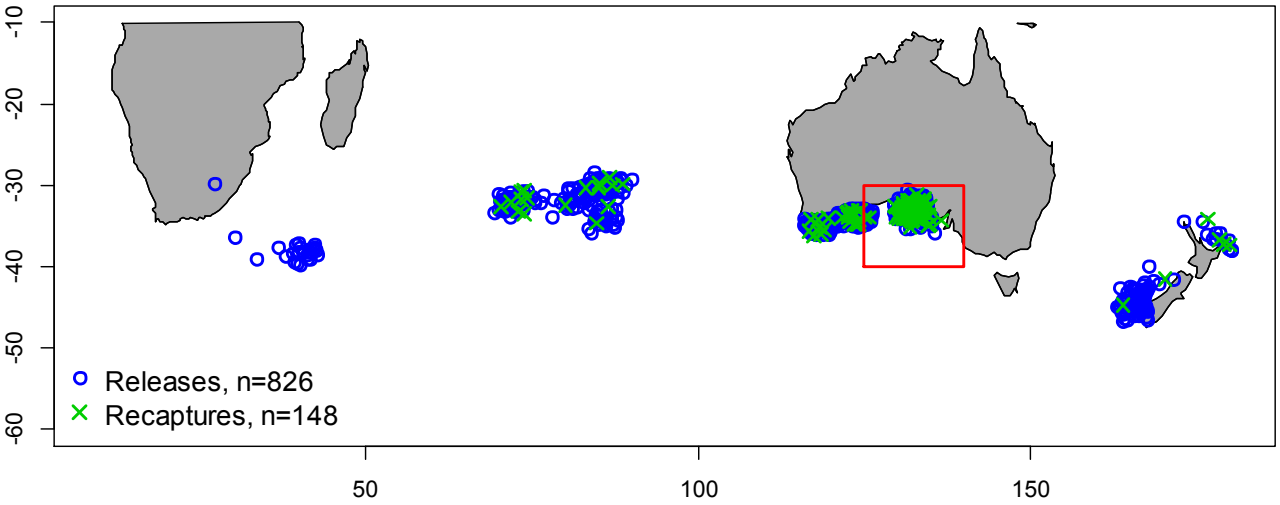
Juvenile southern bluefin tuna



- Juveniles (age ~2-5) make annual cyclic migrations
- Spend winters across southern ocean
- Spend summers in GAB (Dec-Apr)
- Purse-seine fishery worth ~$60 million annually occurs in GAB in summer



Archival tagging of juvenile SBT

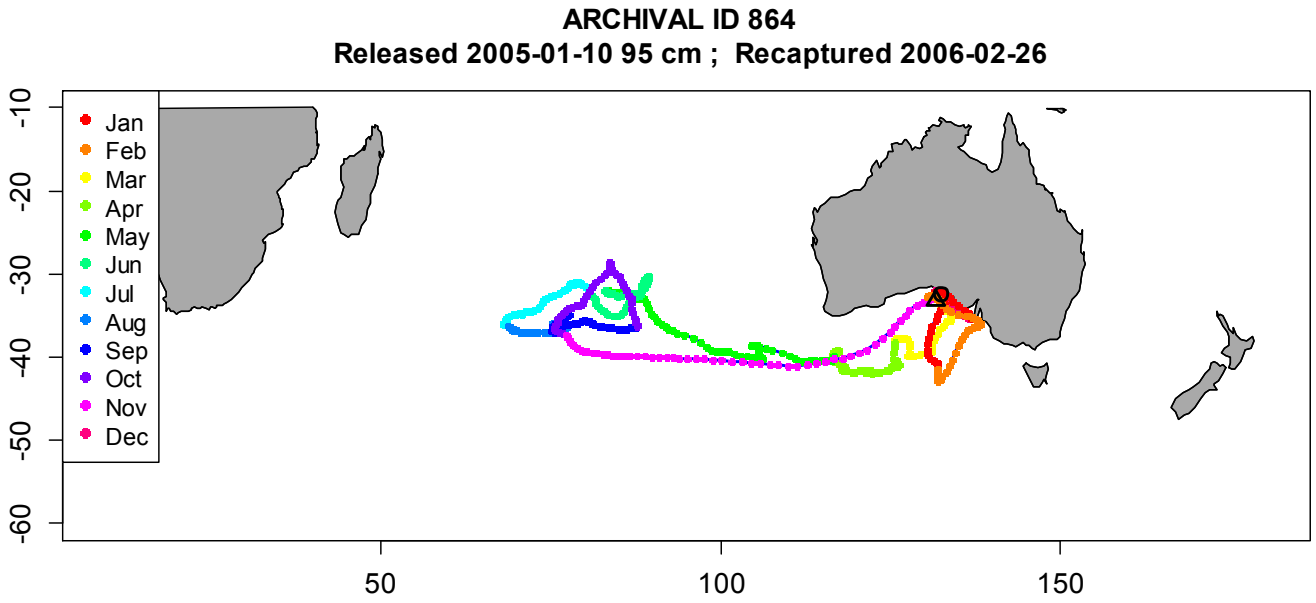


- Tags released in 1998-2008
- Released at ages 1-4
- Recaptured at ages 2-6
- 42% of releases and 78% of recaptures occurred in the GAB (red box)

Basson, Hobday, Eveson and Patterson (2012) *Spatial interactions among juvenile SBT at the global scale: a large scale archival tag experiment*. FRDC Final Report 2003/002.

Estimating tracks from archival tags

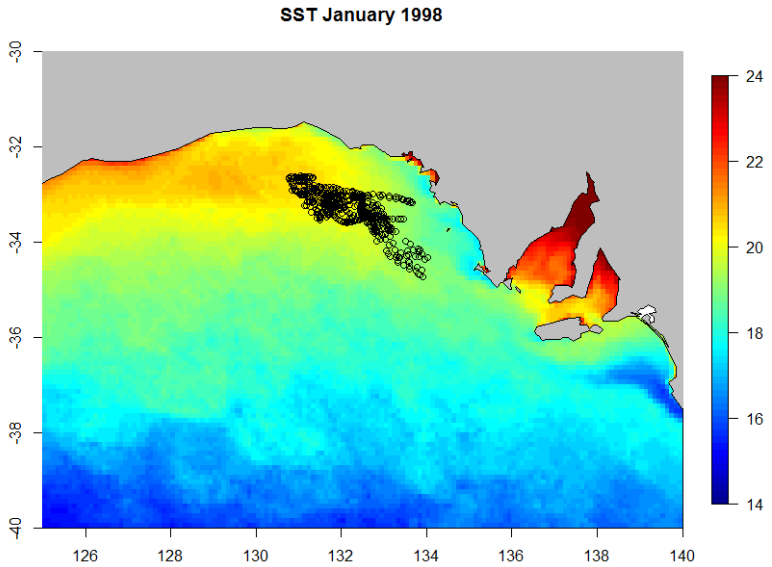
- Daily positions estimated using a state-space model with data inputs:
  - Light record from tag
  - Sea surface temperature (SST) from tag cf remote sensed SST

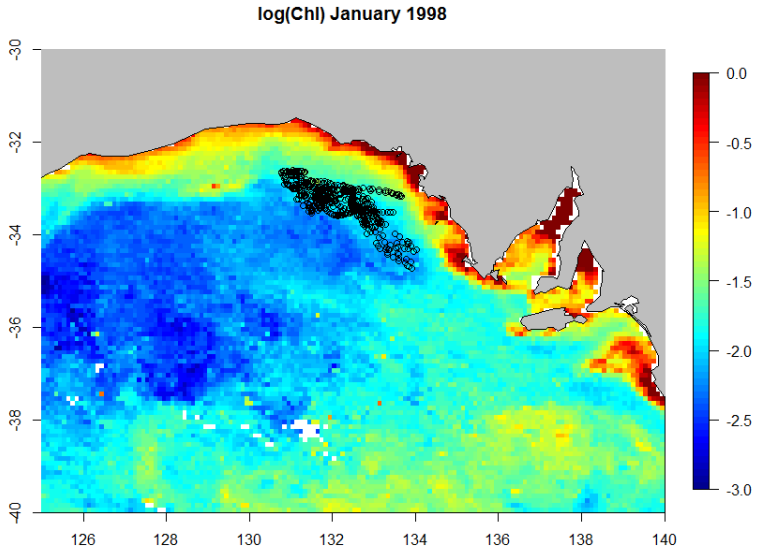


Estimating habitat preference

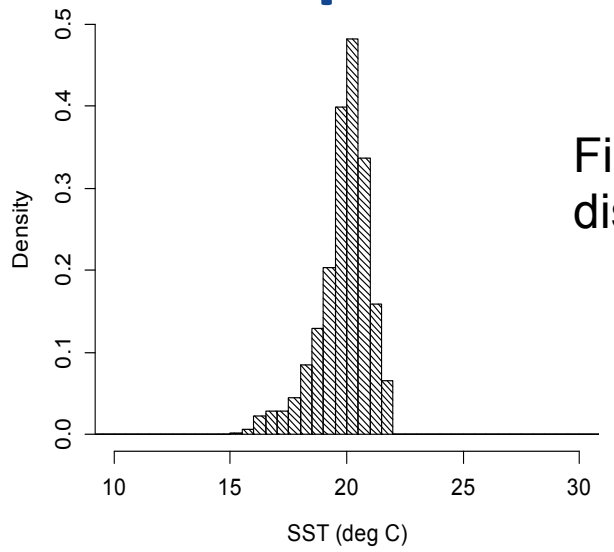
- Compared environmental data *(SST, chlorophyll a, mixed layer depth, bathymetry, wind, frontal density, sea surface height)* for:
  1. entire GAB vs.
  2. locations where fish were found within the GAB

  during Jan, Feb, Mar of 1998-2009
- Those with greatest influence: SST, chl *a* *(to a lesser extent)*



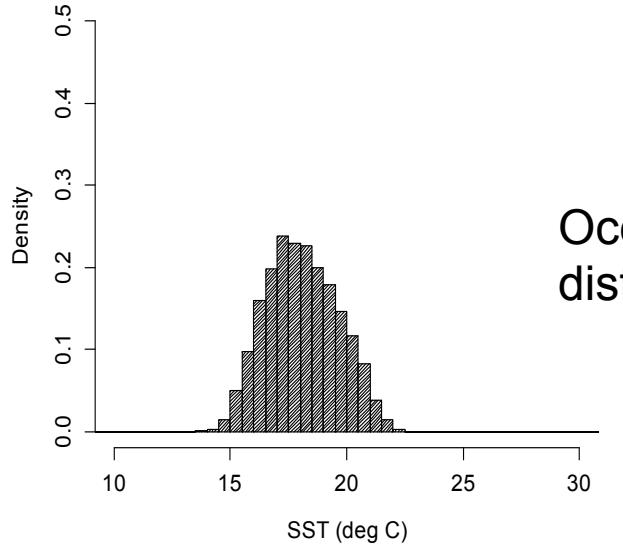


Habitat preference: SST only



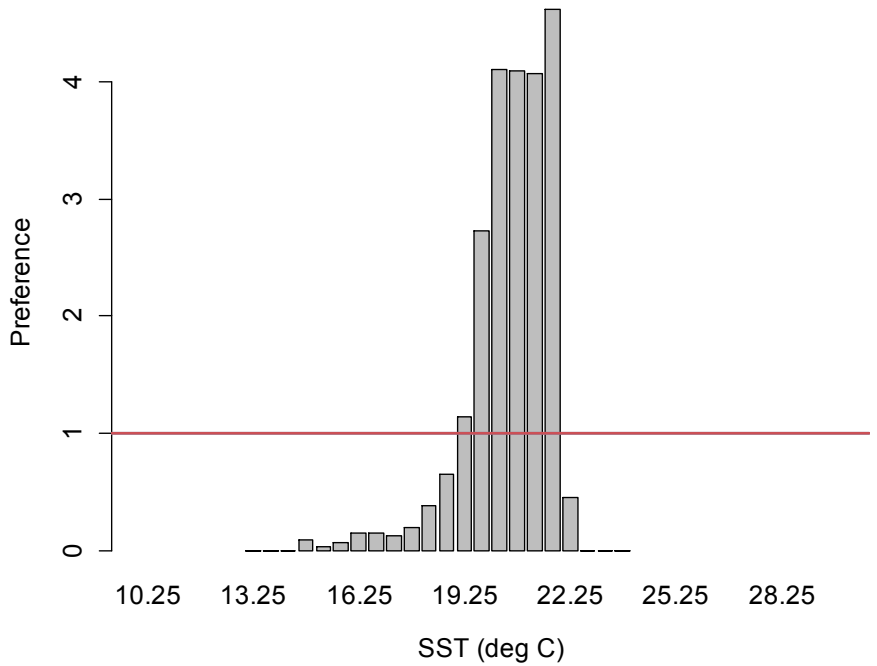
Fish distribution

÷



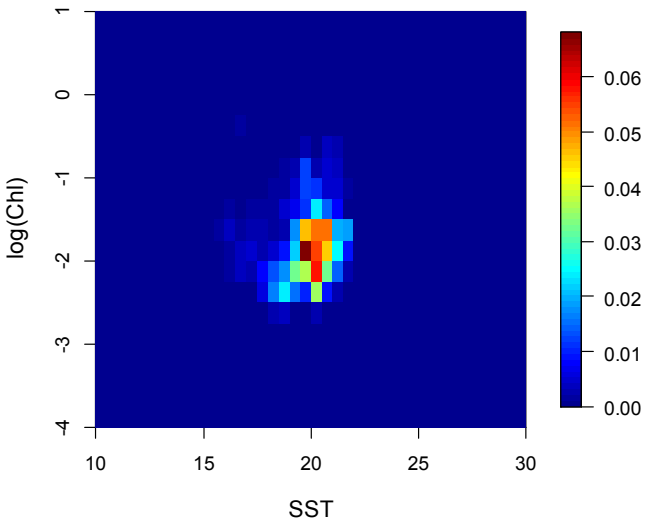
Ocean distribution

Preference curve



1998-2009, Jan-Mar, [-40 -30 125 140]

Habitat preference: SST + chlorophyll *a*



Fish distribution

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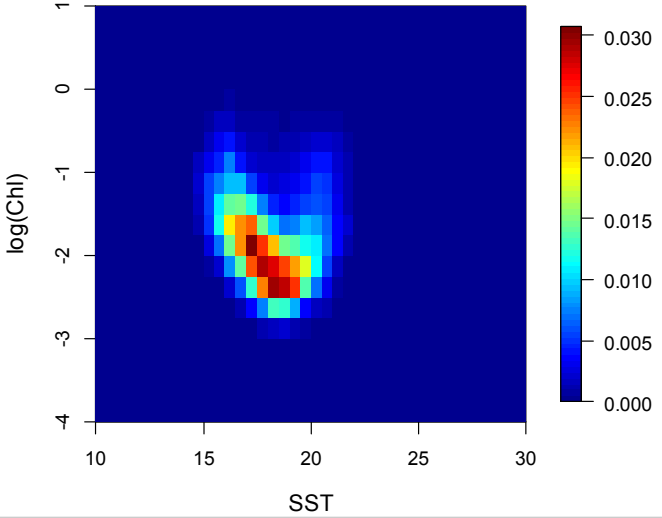
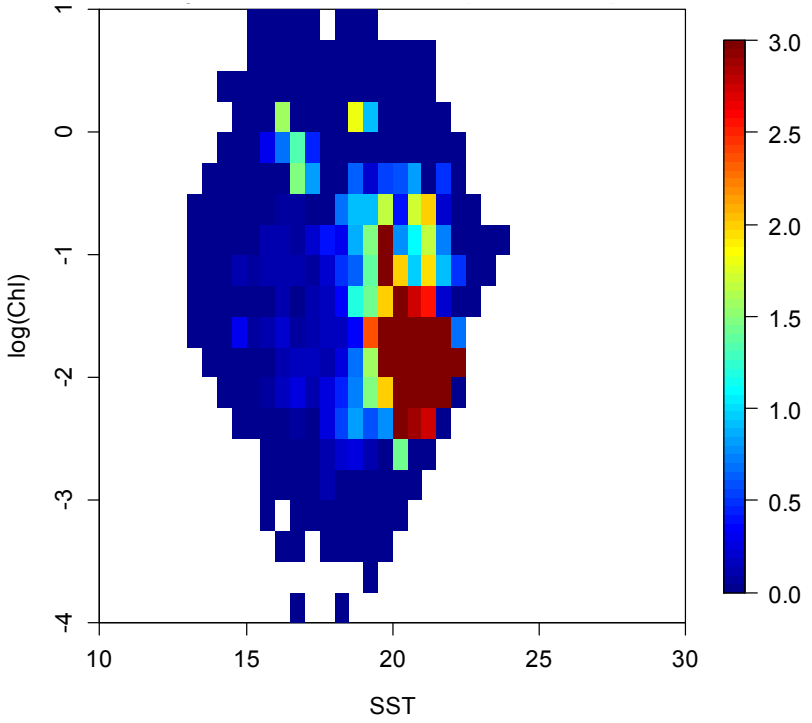


Ocean distribution

Preference surface

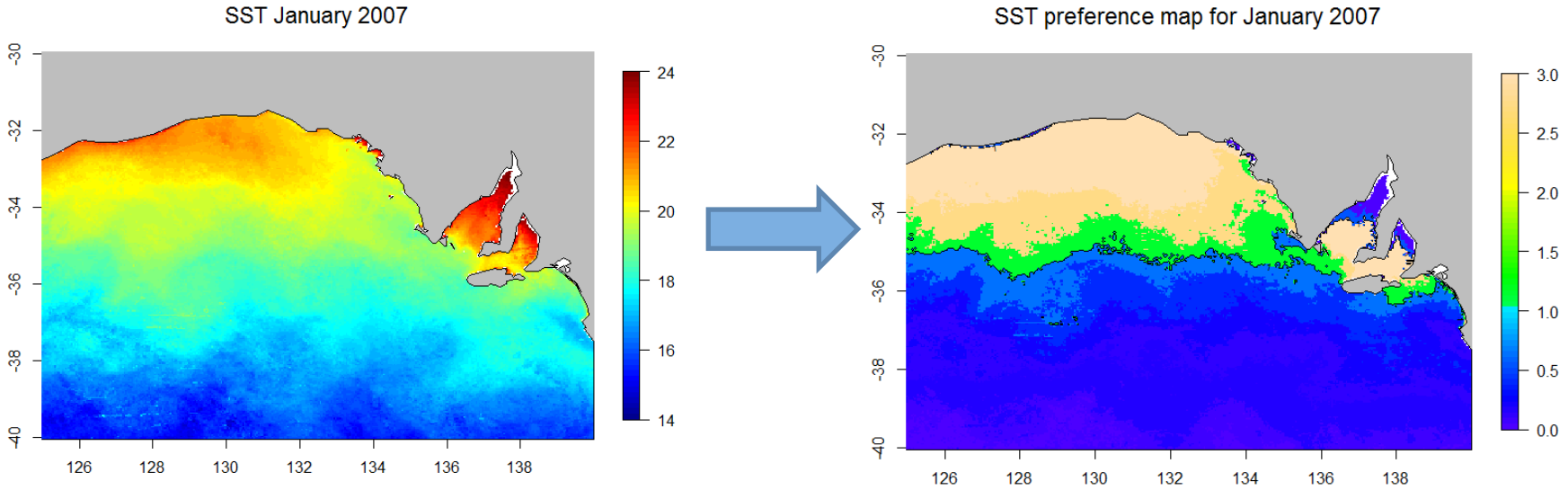


1998-2009, Jan-Mar, [-40 -30 125 140]

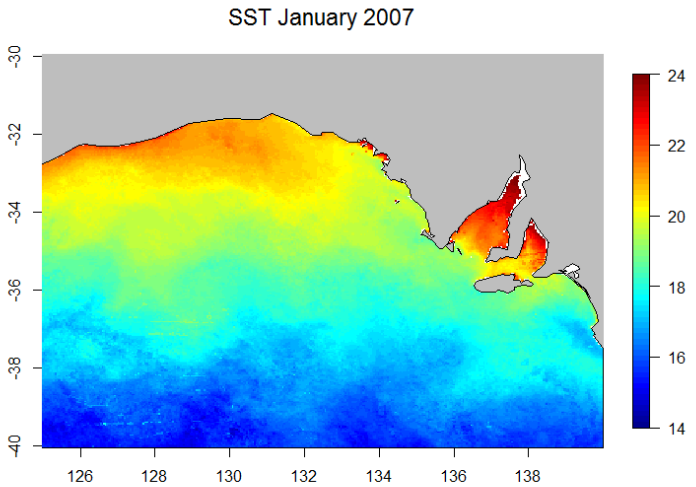
Preferred habitat maps

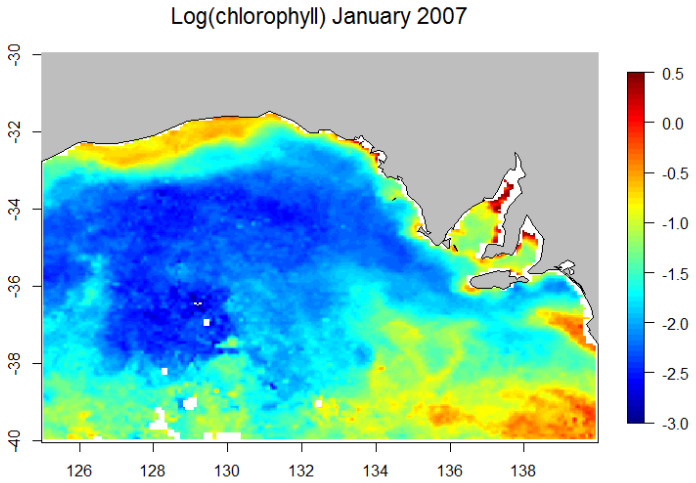
- Produce map showing regions of preferred habitat for any given time period (e.g. Jan 2007)
  - *Get environmental conditions for that time period*
  - *Look up preference value corresponding to environmental conditions at each location*

SST only

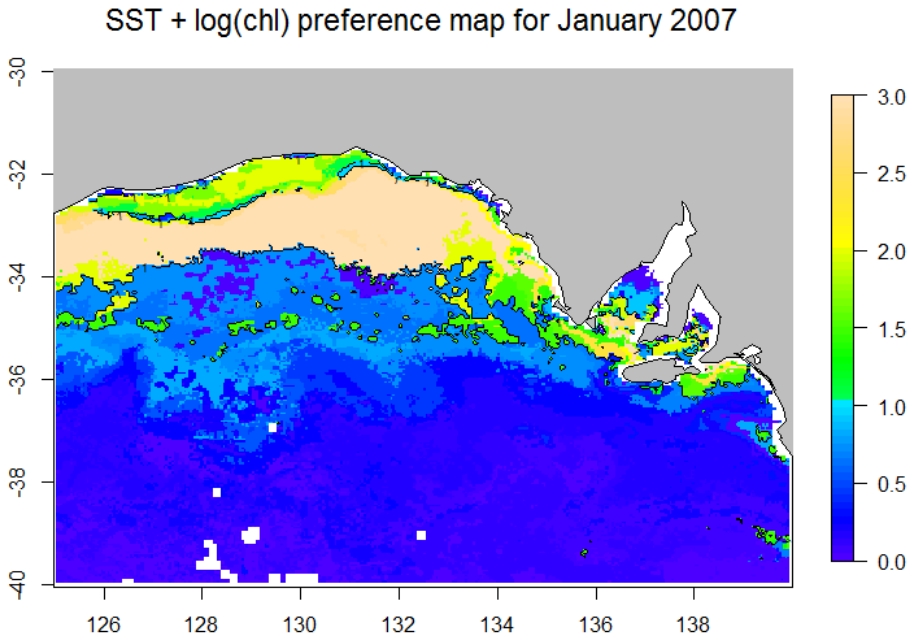


Preferred habitat maps



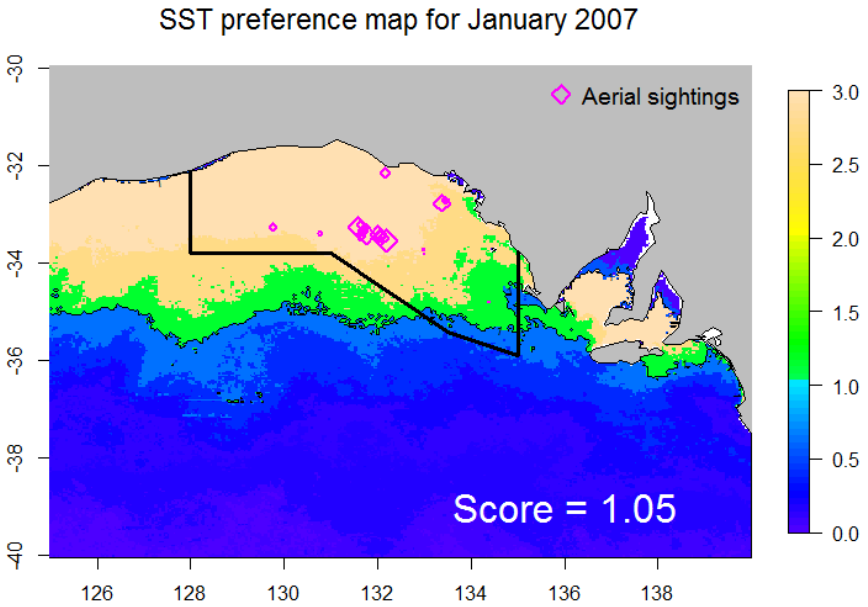


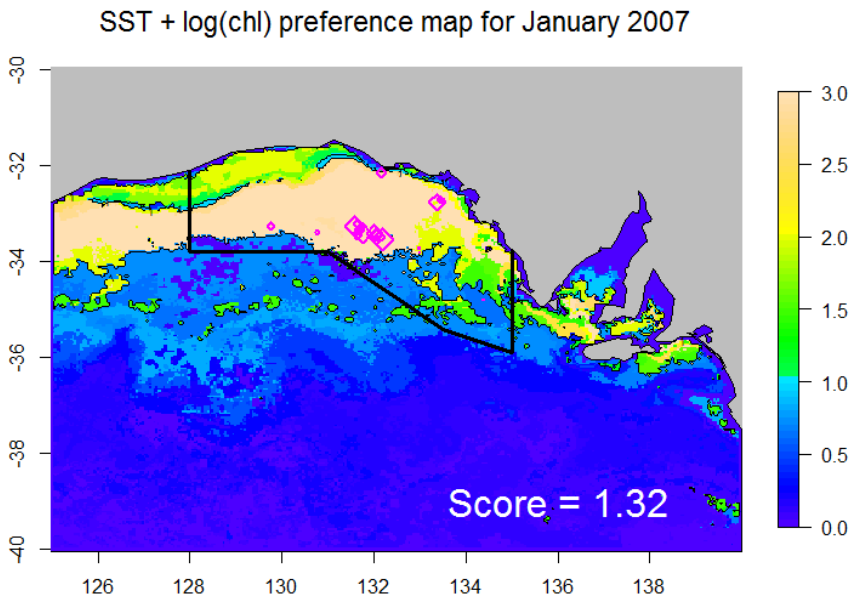
SST + chlorophyll *a*



Validating habitat preferences

- Aerial survey for SBT conducted annually in GAB from Jan-Mar
- Use location of sightings to evaluate habitat preferences
  - *Score = Prop'n sightings within preferred habitat*
    Prop'n survey area containing preferred habitat
  - *Score > 1 means preferences are informative (= 1 if fish randomly distributed)*





Validating habitat preferences

- Consider all years and months of aerial survey data
  - SST alone: scores > 1 in all but one year/month
  - SST + chl *a*: scores > SST alone in all but one year/month

	JANUARY		FEBRUARY		MARCH	
YEAR	SST	+CHL	SST	+CHL	SST	+CHL
1998	1.39	1.42	1.05	1.11	1.11	1.42
1999	1.17	1.28	1.26	1.40	1.55	1.72
2000	1.73	1.83	1.05	1.15	1.06	1.09
2005	1.20	1.42	1.01	1.38	1.41	1.83
2006	1.16	1.30	1.32	1.59	1.08	1.26
2007	1.05	1.32	1.05	1.10	1.08	1.19
2008	1.10	-	1.57	-	1.02	-
2009	1.01	1.09	1.10	1.21	0.93	1.17
2010	1.02	1.18	1.22	1.33	1.10	1.12
2011	1.00	0.53	1.07	1.29	2.31	2.28
2012	1.01	1.27	1.02	1.13	1.01	1.09
2013	1.06	1.22	1.02	1.24	1.03	1.01
2014	1.02	1.02	1.03	1.08	1.03	1.06

score ≥ 1

+chl better than SST alone

score < 1

Forecasting preferred habitat

- Use POAMA forecasts of SST to predict regions of preferred habitat

- POAMA does not currently forecast chl *a*, so can only provide SST-based forecasts

- Forecasts are issued for next 2 fortnights and next 6 calendar months

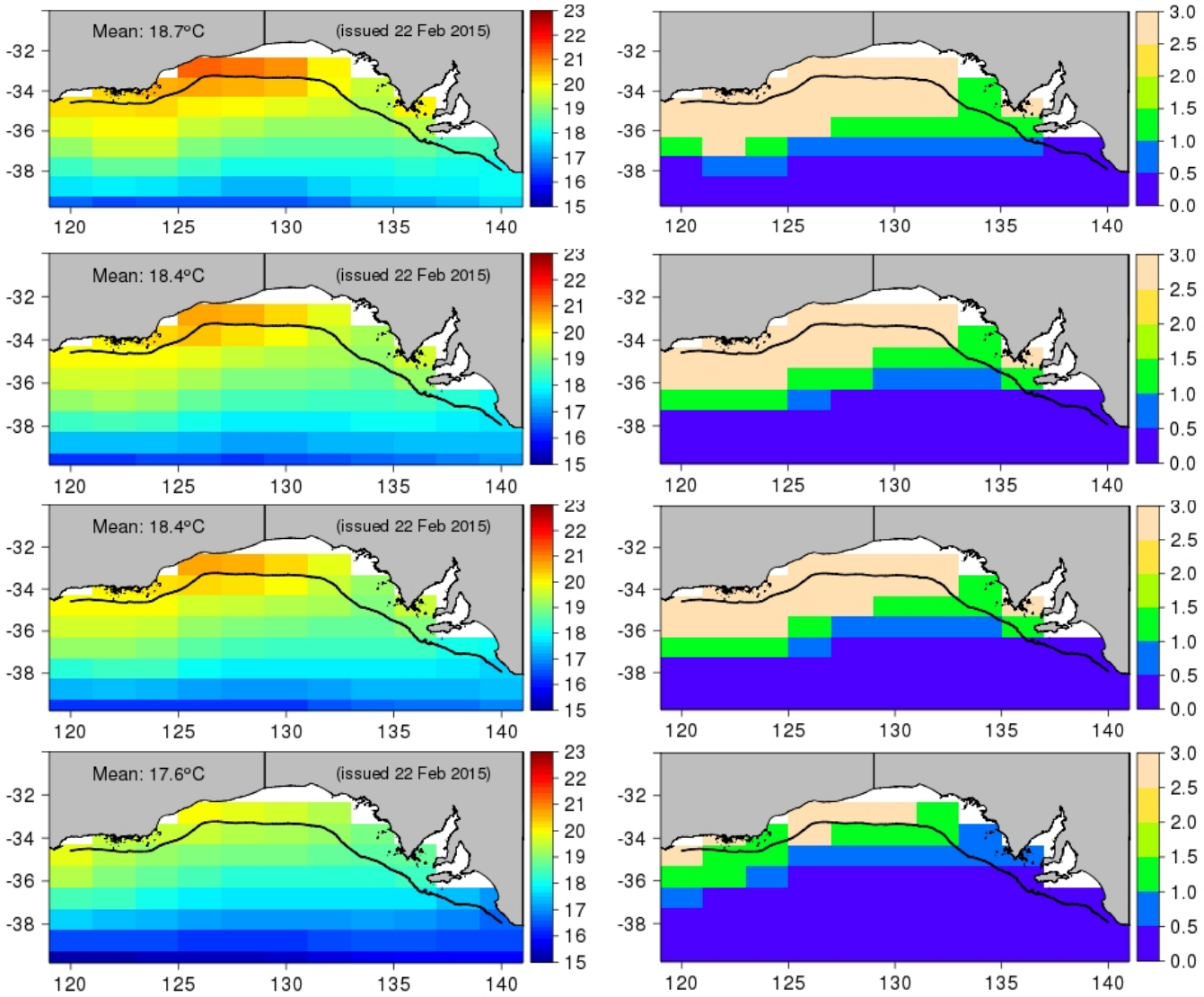
Forecasts issued 22 Feb 2015

Fortnight 1:
22 Feb – 7 Mar

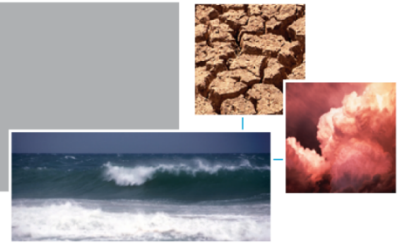
Fortnight 2:
8 Mar – 21 Mar

Month 1:
March

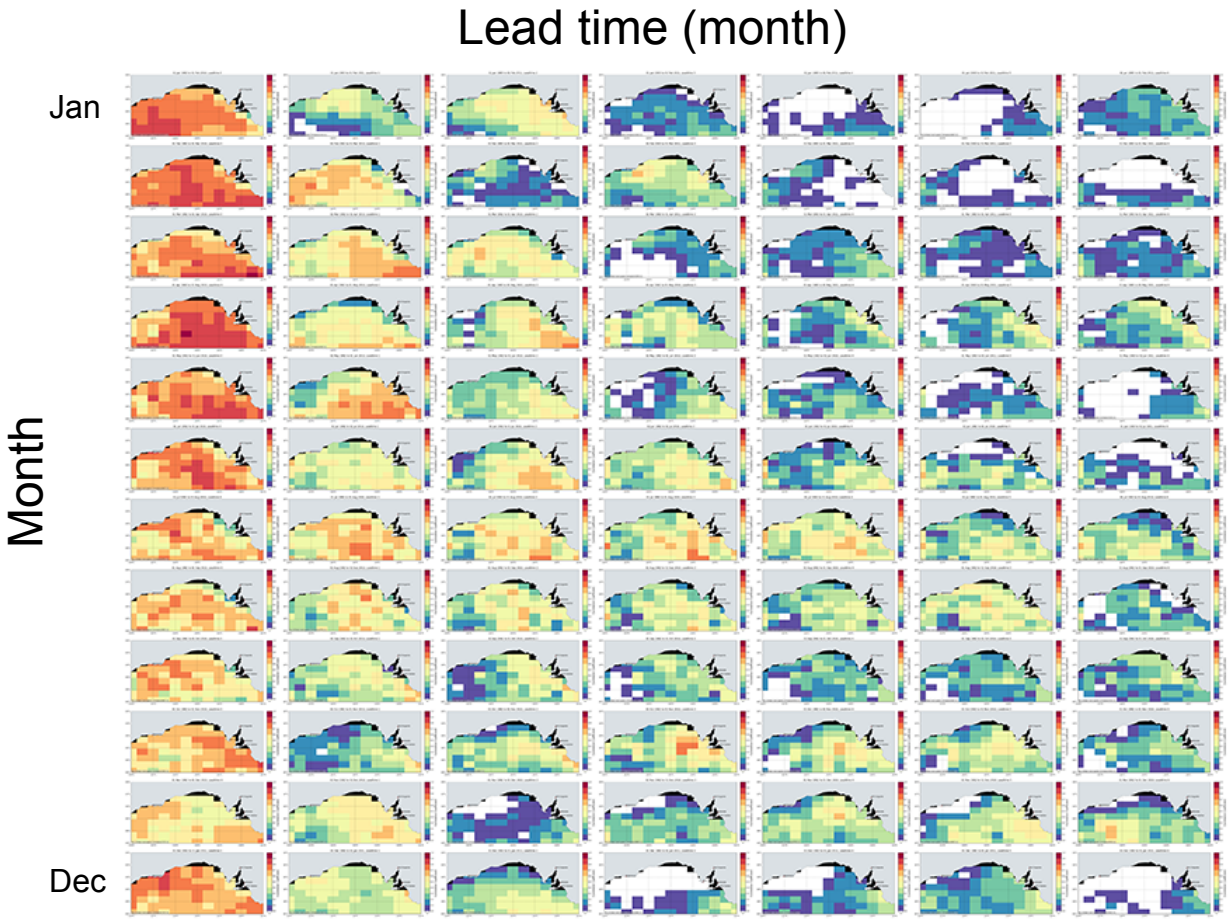
Month 2:
April



Forecast skill in GAB



- For Jan-Mar, SST forecasts lead times ~2 months



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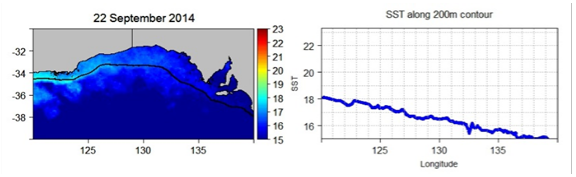
Delivery of forecasts to industry

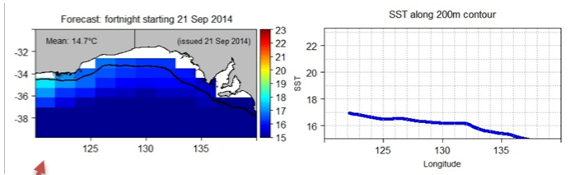
- Website developed specifically for this purpose
- Automated to update daily
- Regular engagement with industry, particularly through industry co-investigator
- Website modified in response to feedback
- Contains much more than just the forecasts…
- http://www.cmar.csiro.au/gab-forecasts

Website information

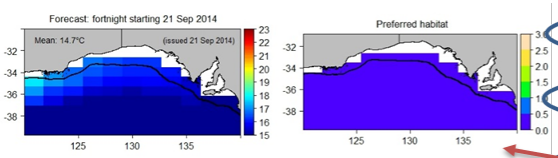
Maps of recent SST and chlorophyll conditions



Forecasts of SST up to 2 months in future

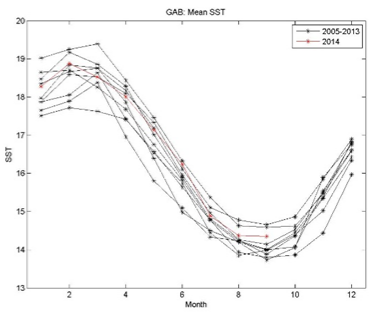


Forecasts of preferred SBT habitat

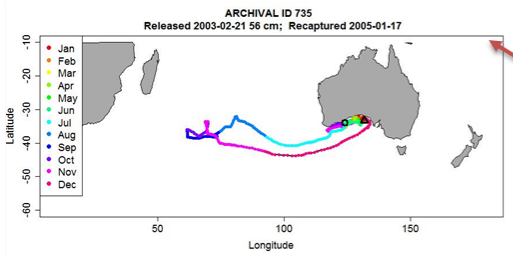


- Home
- Observed conditions
- SST forecasts
- Habitat preference forecasts
- Historical SST
- Case studies
- Estimating habitat preferences
- Useful links

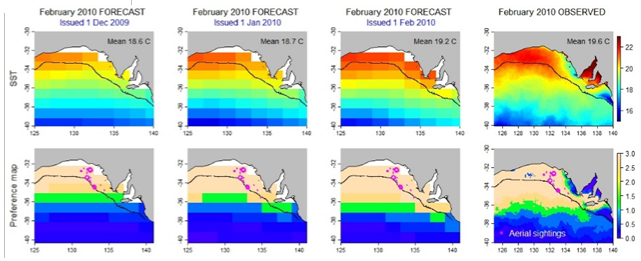
Historical SST and trends in GAB



How to calculate habitat preferences



Case studies of recent seasons



References, links and contact details

POAMA - learn more about the underlying seasonal forecast model on the POAMA site: http://poama.bom.gov.au/about_poama2.shtml

Delivery - www.cmar.csiro.au/gab-forecasts

Adaptation yet?

In the first year

10 major fishing companies

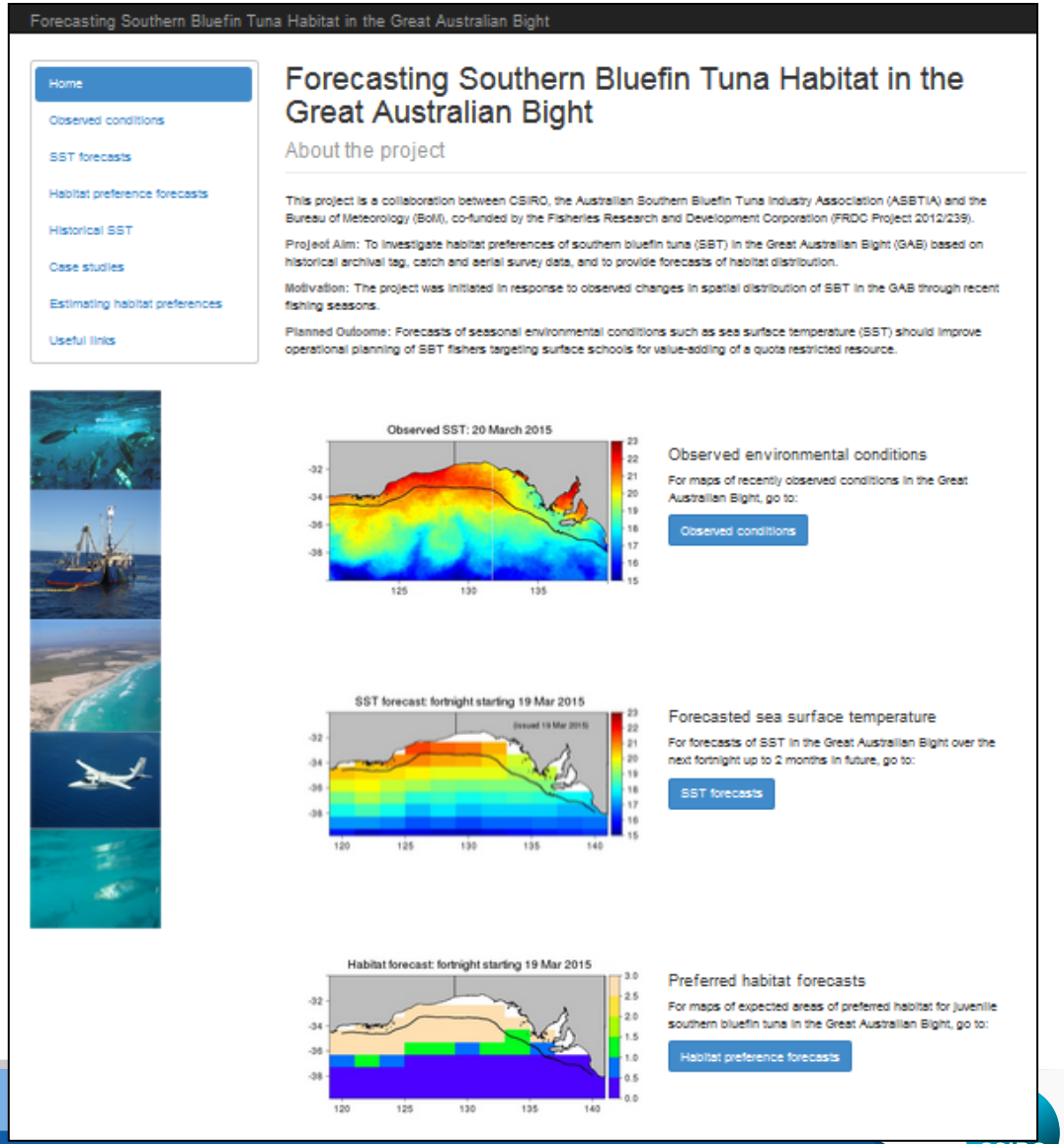
- All used website

8 used in decision-making

- 6 made different decision
- 2 made "do nothing different" decision

- (when and where to fish)
- (economic benefits)

Eveson et al (2015) Fish Res



2. Salmon aquaculture

Tasmanian Salmon

Management issue:

Farmed salmon grown towards upper thermal limit in summer. Sea temperatures linked to salmon growth and health.

Management need:

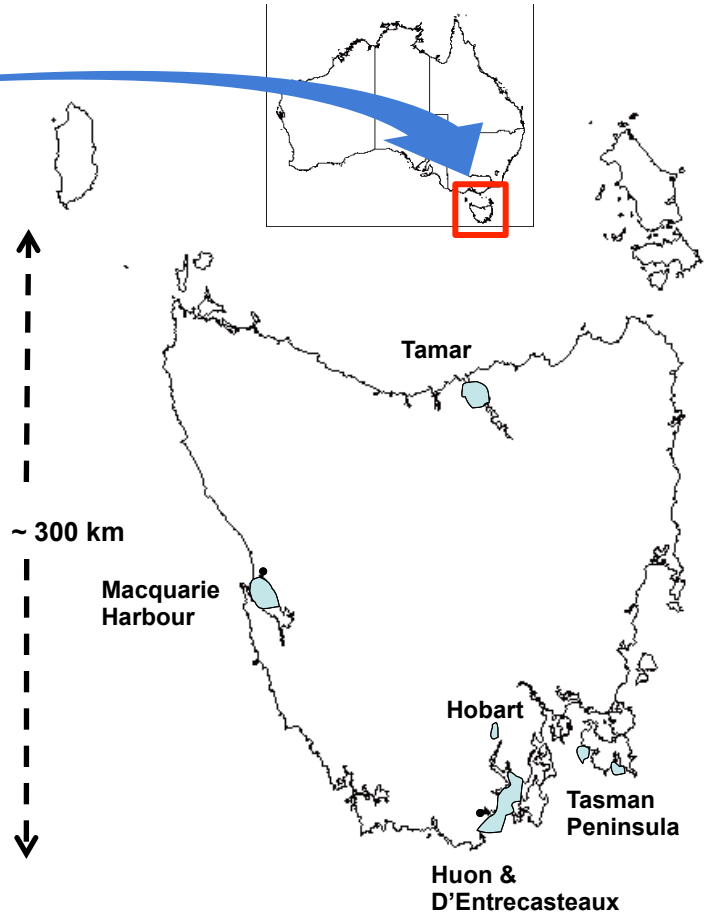
Reduce vulnerability to temperature extremes under climate change

Management solution

Freshwater bathing, diet

Management support:

Seasonal forecasts to assist future planning activities



Hobday et al in press; Spillman & Hobday 2014

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2A. Assess needs

Tasmanian Salmon A$500M
Liaised with Salmon Growers Association
Require information 1 month to a season ahead regarding anomalously warm conditions
Summer sea surface temperature
Ocean data reanalyses, historical farm temperature data

Project funded by the Tasmanian Salmon Growers Association

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Bureau of Meteorology

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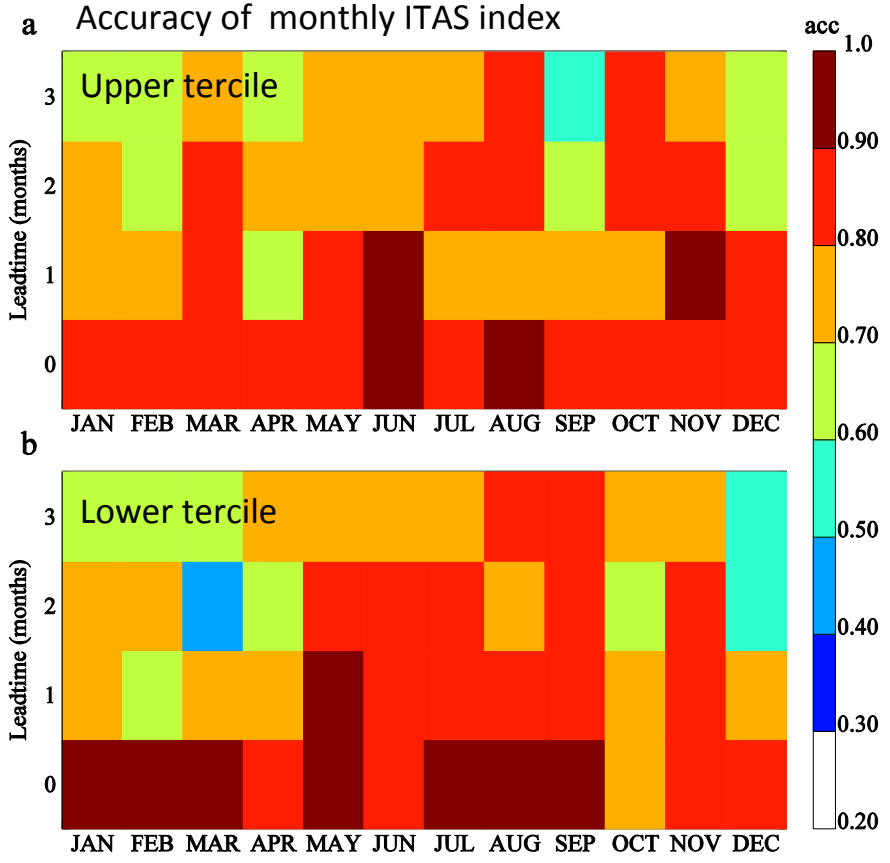
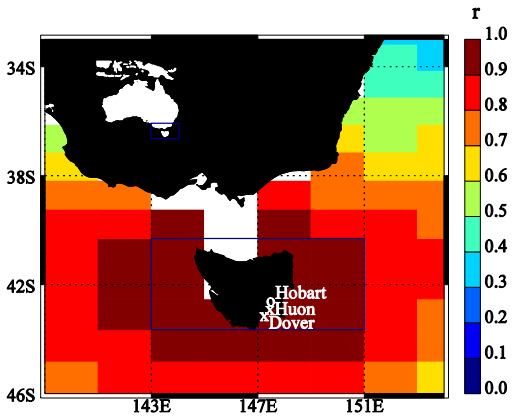
2B. Development

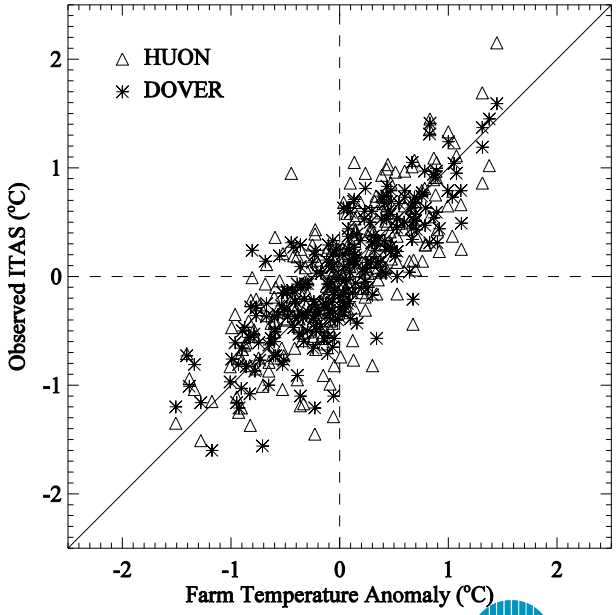
i. Assess skill of POAMA ITAS index forecasts



Model skill for 1992-2010



ITAS index strongly correlated around Tasmania



Correlations of ITAS index with farm data of 0.76 and 0.83

Spillman & Hobday 2014

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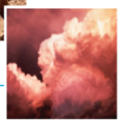
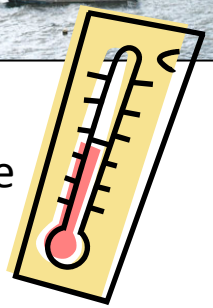
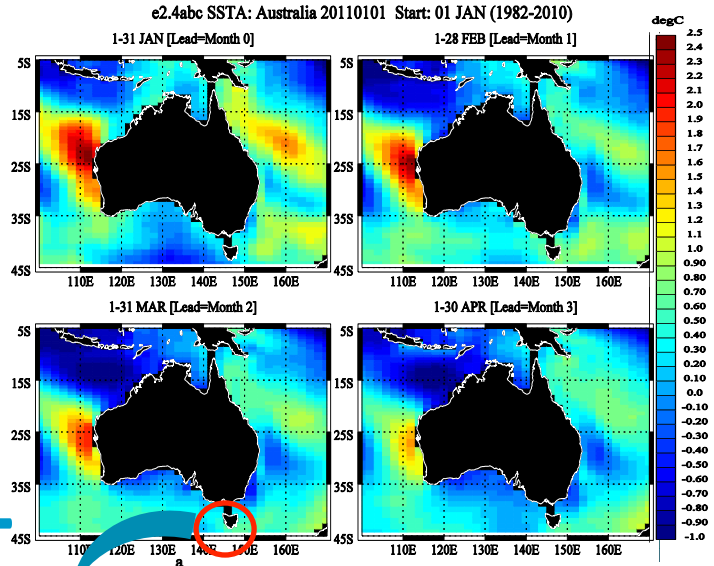
2B. Development

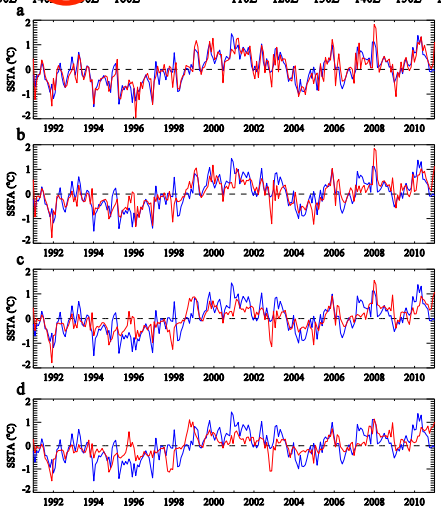



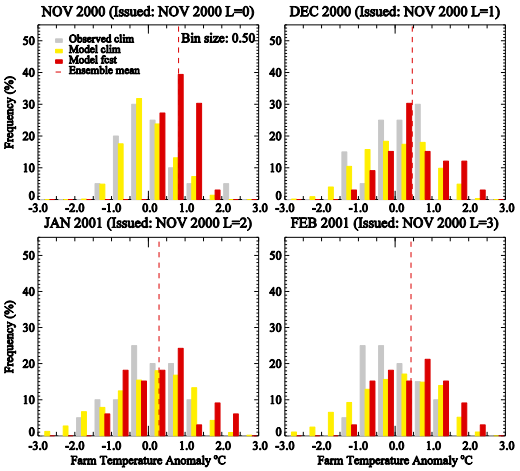

ii. Tailored salmon farm forecast products

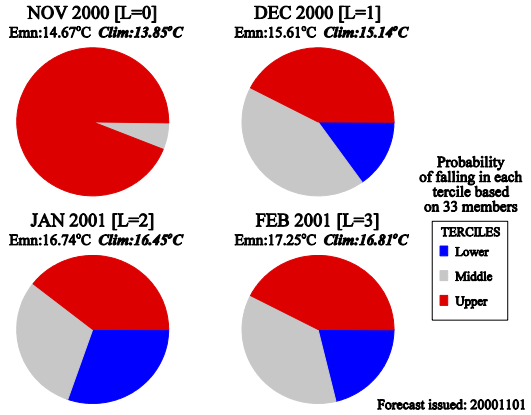
farm temperature data & monthly climatologies











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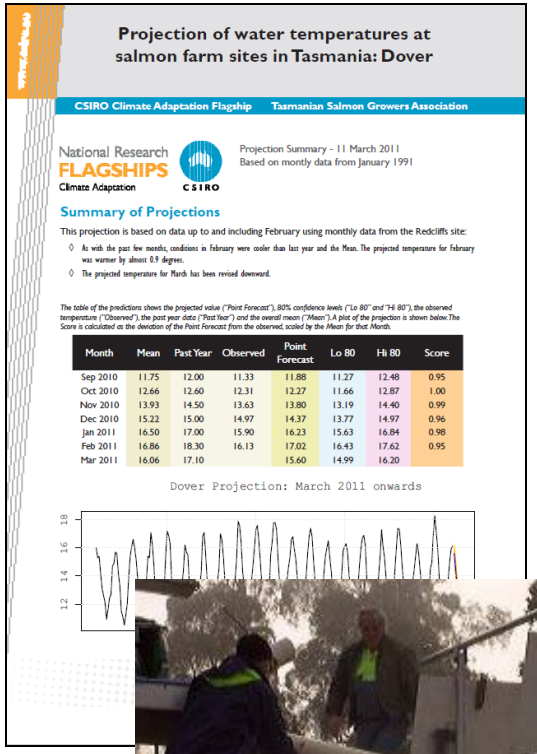
2C. Implementation

Tasmanian salmon

- Forecast delivery via monthly emailed reports
- Meetings & education
- Industry feedback

➢ Information to allow salmon cooperatives to better manage farms in the likelihood of a hot summer

➢ Strategies include freshwater bathing, put on more staff, order different feed, thin out pens, shifting pens to cooler waters



Projection of water temperatures at salmon farm sites in Tasmania: Dover

CSIRO Climate Adaptation Flagship Tasmanian Salmon Growers Association

National Research FLAGSHIPS Climate Adaptation CSIRO

Projection Summary - 11 March 2011
Based on montly data from January 1991

Summary of Projections

This projection is based on data up to and including February using monthly data from the Redcliffs site:

- As with the past few months, conditions in February were cooler than last year and the Mean. The projected temperature for February was warmer by almost 0.9 degrees.
- The projected temperature for March has been revised downward.

The table of the predictions shows the projected value ("Point Forecast"), 80% confidence levels ("Lo 80" and "Hi 80"), the observed temperature ("Observed"), the past year data ("Past Year") and the overall mean ("Mean"). A plot of the projection is shown below. The Score is calculated as the deviation of the Point Forecast from the observed, scaled by the Mean for that Month.

Month	Mean	Past Year	Observed	Point Forecast	Lo 80	Hi 80	Score
Sep 2010	11.75	12.00	11.33	11.88	11.27	12.48	0.95
Oct 2010	12.66	12.60	12.31	12.27	11.66	12.87	1.00
Nov 2010	13.93	14.50	13.63	13.80	13.19	14.40	0.99
Dec 2010	15.22	15.00	14.97	14.37	13.77	14.97	0.96
Jan 2011	16.50	17.00	15.90	16.23	15.63	16.84	0.98
Feb 2011	16.86	18.30	16.13	17.02	16.43	17.62	0.95
Mar 2011	16.06	17.10		15.60	14.99	16.20	

Dover Projection: March 2011 onwards

Spillman & Hobday 2014

Australian Government
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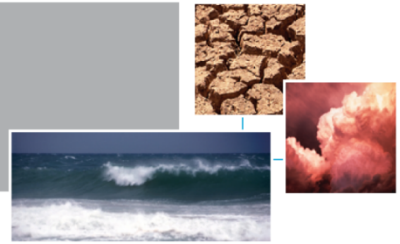
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

3. Prawn aquaculture



Queensland Prawns

Management issue:

Farmers wish to optimize prawn growth and yield

Management need:

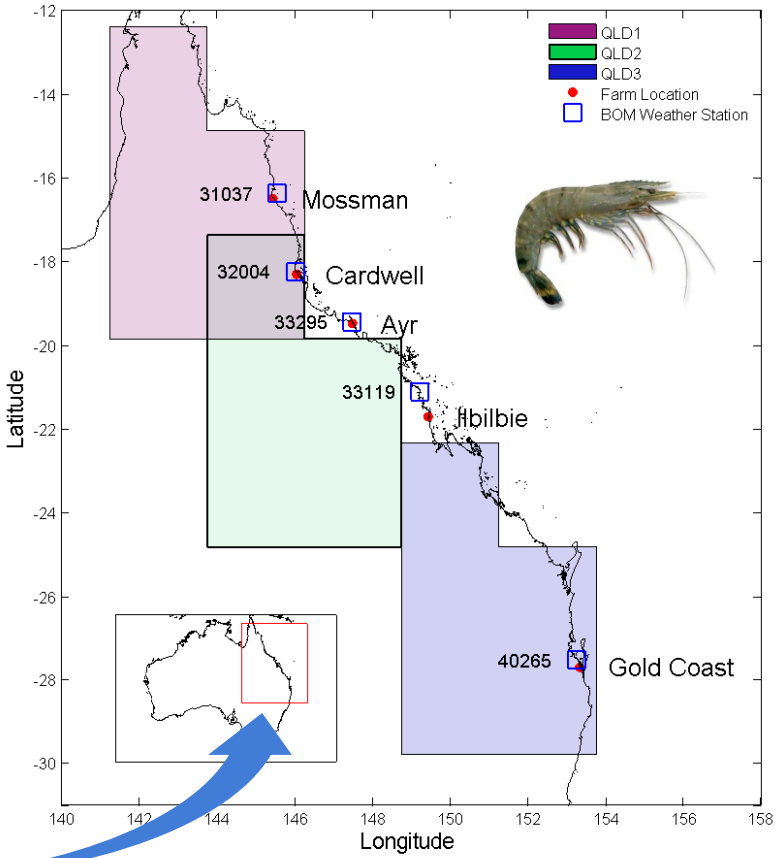
Reduce vulnerability to cool temperature & rainfall extremes

Management solution:

Timing of stocking & harvesting, diet, ordering supplies in advance,

Management support:

Seasonal forecasts to assist future planning activities



Spillman et al 2015

Australian Government
Bureau of Meteorology

CSIRO

3A. Assess needs

Queensland prawns

Queensland prawns A$70M
Liaised with the Australian Prawn Farmers Association and individual farm managers along coast
Require information 2 weeks to a season ahead regarding anomalously warm or cold conditions, heavy rainfall or tropical cyclones
Air temperature & rainfall year round
Weather station rainfall & air temperature data , pond temperature data

Project funded by the Queensland Government Cyclone Yasi Recovery Fund.

Australian Government
Bureau of Meteorology

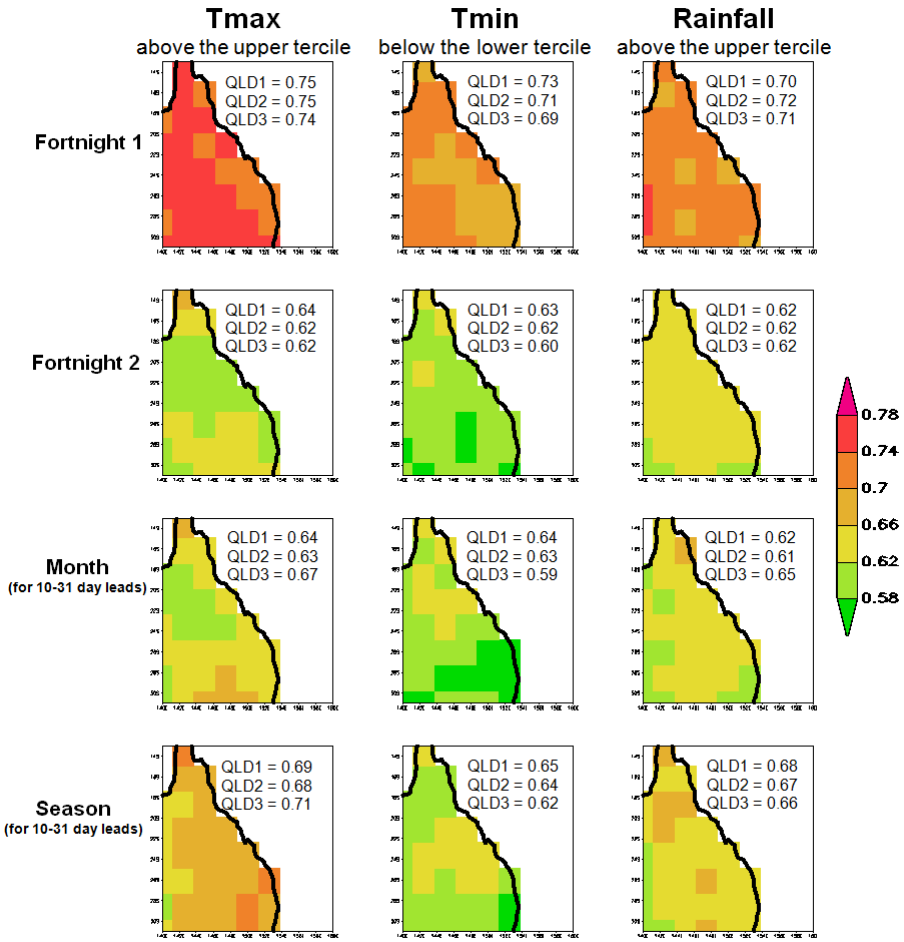
Spillman et al 2015

CSIRO

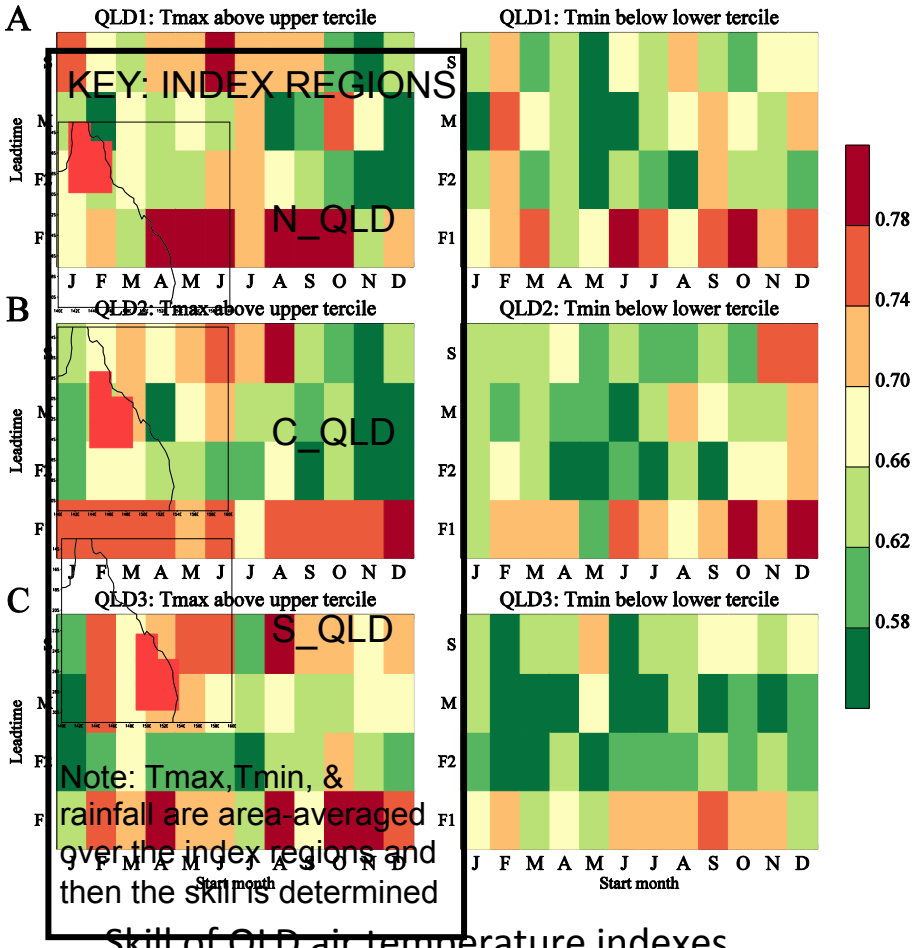
3B. Development

Queensland prawns

i. Assess skill of POAMA rainfall & air temperature forecasts



Model skill for 1981-2010



Note: Tmax,Tmin, & rainfall are area-averaged over the index regions and then the skill is determined

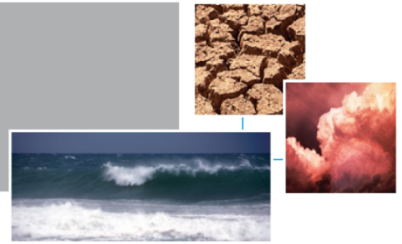
Skill of QLD air temperature indexes

Spillman et al 2015

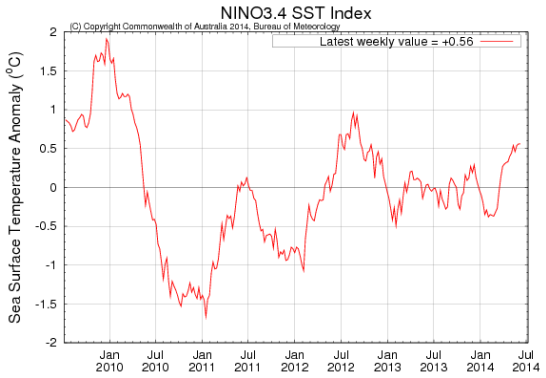
Australian Government
Bureau of Meteorology

CSIRO

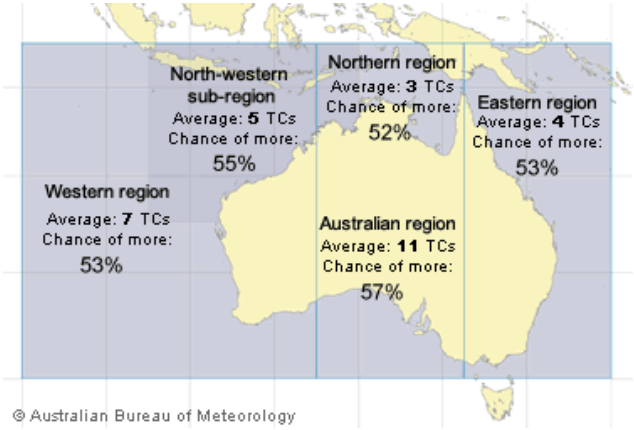
3C. Implementation



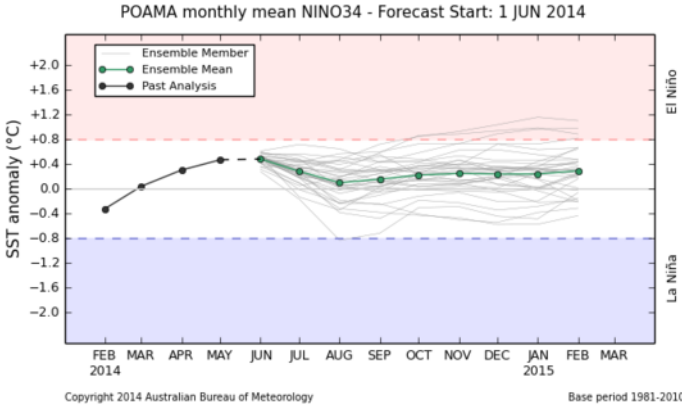
ii. Forecasts scale: National → Regional → Farm



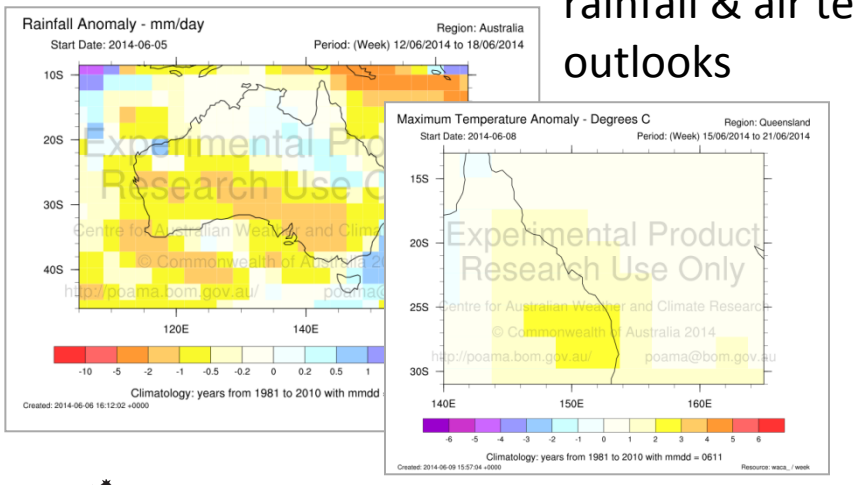
Current ENSO conditions



National tropical cyclone season outlook



Latest POAMA ENSO forecasts



National & regional rainfall & air temp outlooks

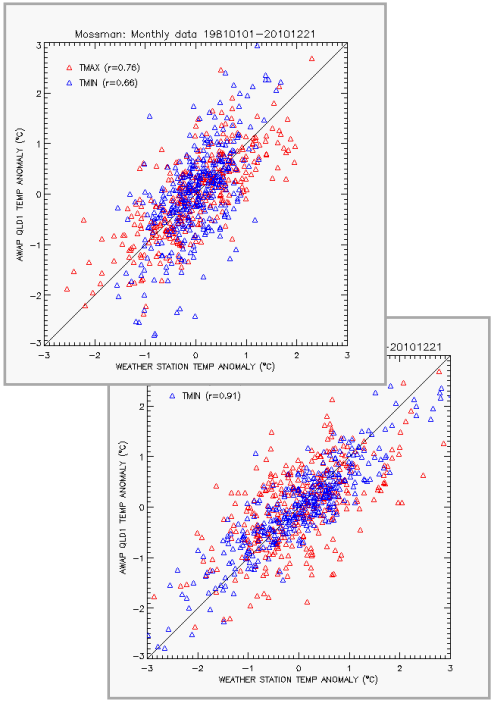
Australian Government
Bureau of Meteorology

CSIRO

3B. Development

Queensland prawns

iii. Tailored farm forecast products



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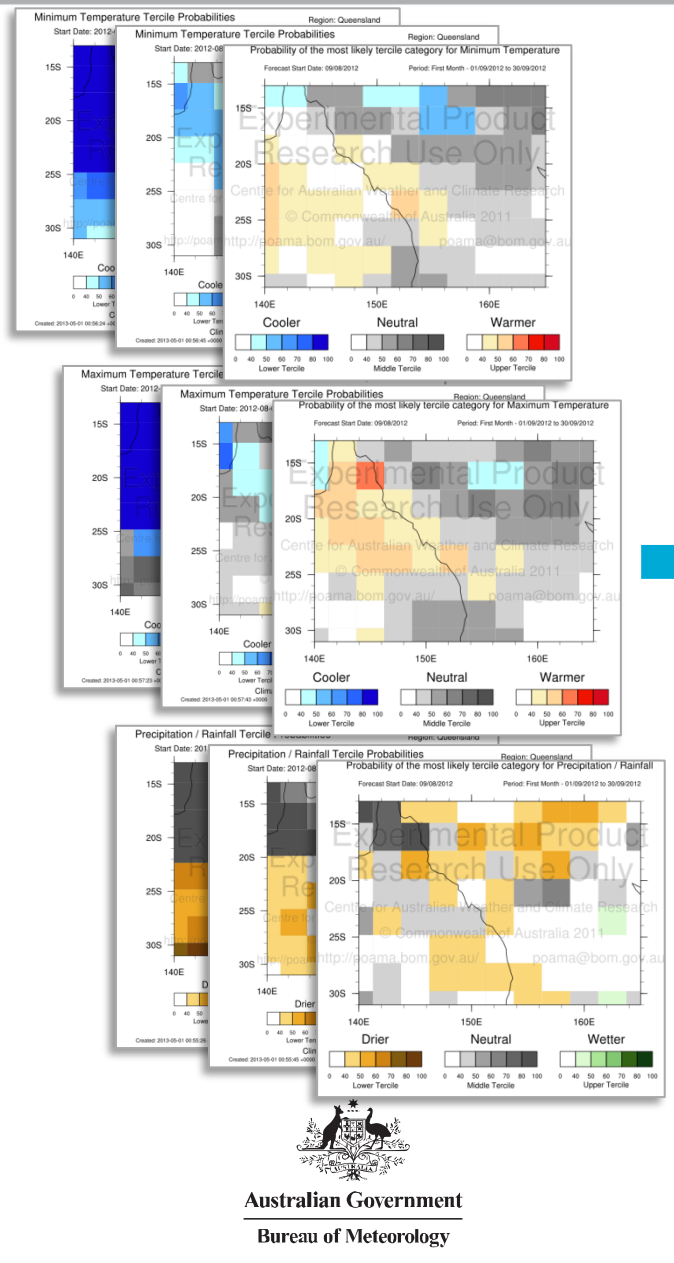
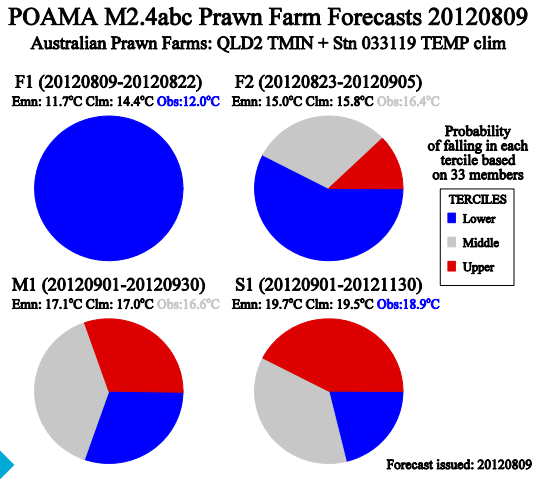
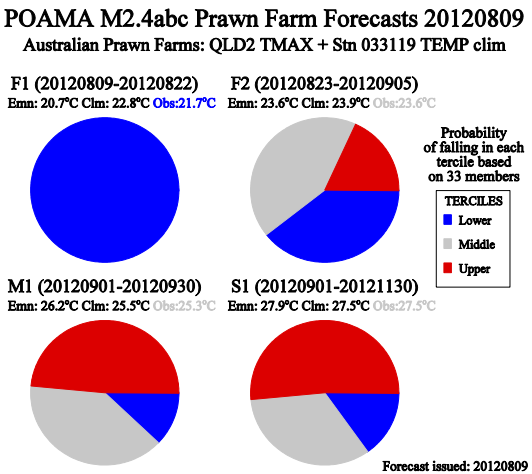


Observed relationships between Bureau weather stations and QLD indexes derived from AWAP dataset





Australian Government
Bureau of Meteorology

CSIRO

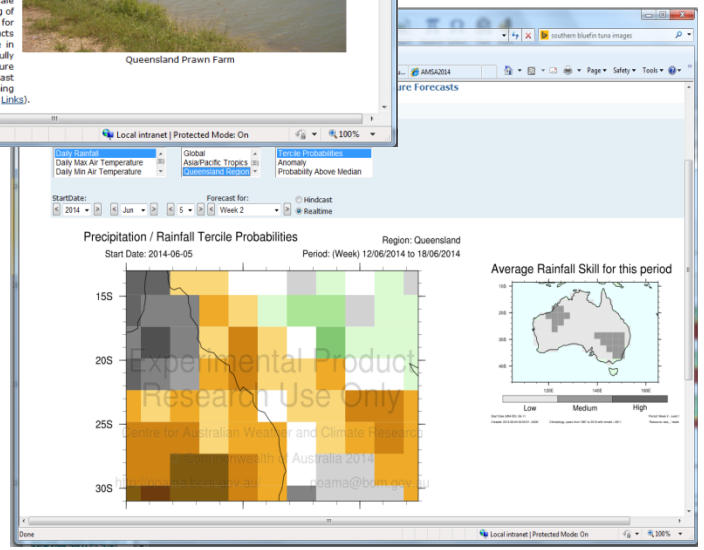
3C. Implementation

Southern bluefin tuna

- Web-based forecasts
- Farm visits very successful
- Industry award

➢ Information to allow prawn farmers to implement strategies to optimise prawn growth & yield

➢ Strategies include timing of seeding & harvest, flushing of ponds, pre-order feed, secure infrastructure, target Christmas and/or Easter markets



Australian Government
Bureau of Meteorology

http://www.poama.bom.gov.au

CSIRO

Development stages for fishery & aquaculture forecast tools

A. Assess needs

Define management or industry need

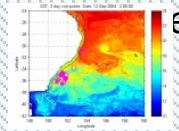
Determine critical variables & decision timescales

Verification data

B. Development

Assess skill using POAMA hindcast

Produce habitat distribution



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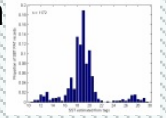
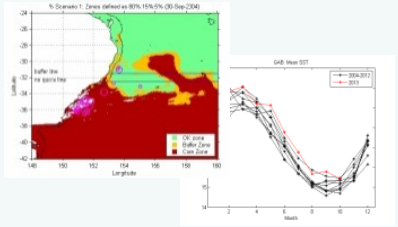


Forecast products



C. Implementation

Forecast delivery

Support & education

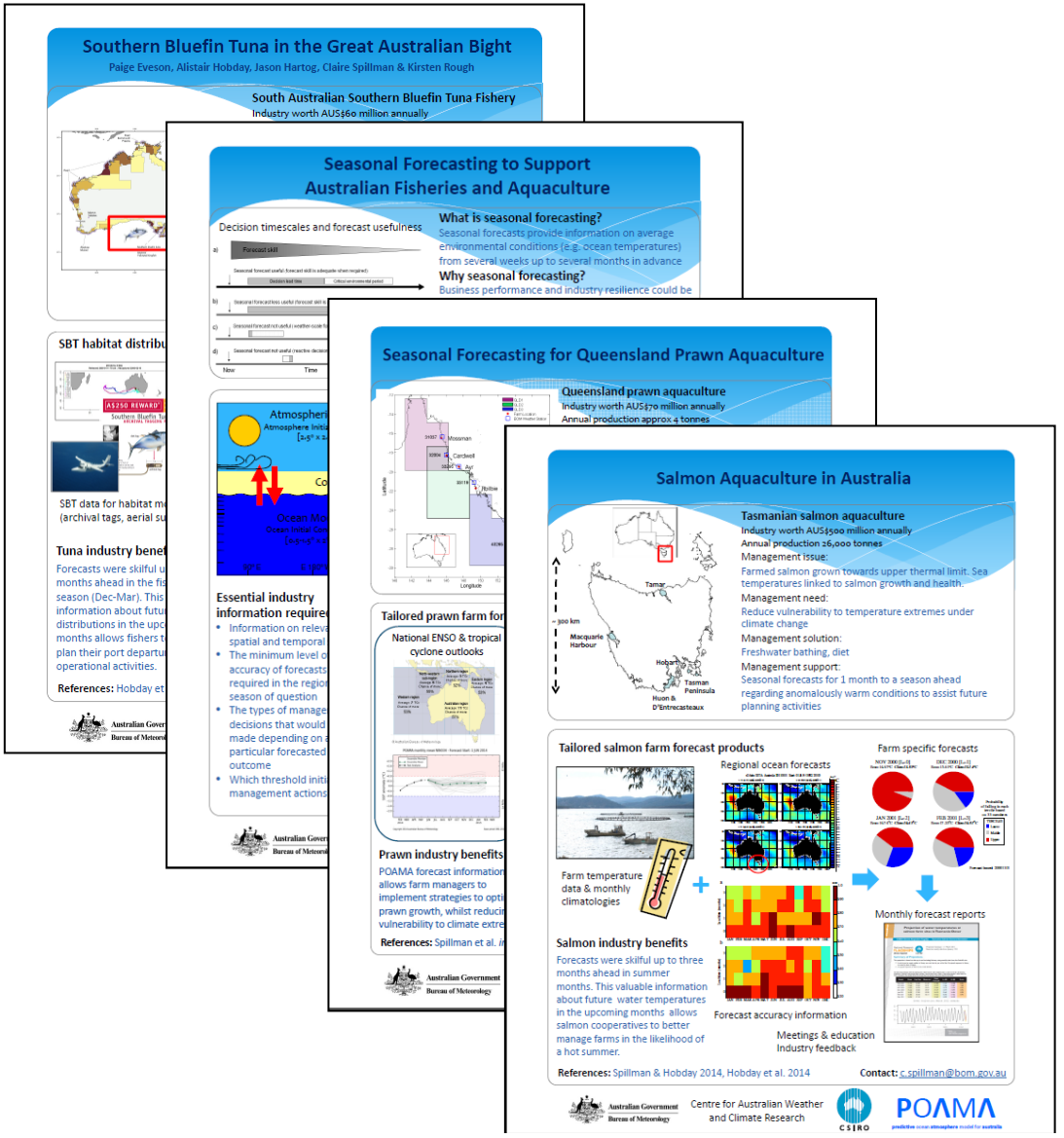
End user decision

User feedback

Hobday et al in press

Range of delivery outputs

- Websites
- Emails
- Summary sheets
- Publications
- Conferences
- Industry meetings



State of play

Example	action	
Longline fishery (managers)	Spatial management Bycatch reduction	Ongoing
Purse seine fishery (fishers)	Spatial maps Economic efficiency	Ongoing
Salmon (farmers)	Environmental forecasts Risk reduction and efficiency	Ceased – different risk management
Prawns (farmers)	Environmental forecasts Economic efficiency	Ongoing – but little engagement
Recreational pelagic fish (fishers, charter boats)	Spatial distribution Fishing opportunity	pending

For these examples….future research

Critical information:

- Information on relevant spatial and temporal scales
- The minimum level of skill or accuracy of forecasts required in the region in the season of question
- The types of management decisions that would be made depending on a particular forecasted outcome

Very useful information:

- Which threshold initiates management actions?
  E.g. must the forecast indicate 90% certainty of an outcome before action is taken or is a probability of 60% sufficient?
- The economic cost/benefit value of forecasts to the industry?

Hobday et al in press

Lessons learned

Essentials:

- Strong industry engagement and partnership
- A clear understanding of the end user skills and how they might use forecast product
- A model with useful skill in the region of interest
- Forecast product delivery mechanism that suits the end user
- Industry feedback for refinement of forecast products

Very useful:

- Industry advocate or liaison officer
- Farm visits and face-to-face end user meetings
- Historical industry data

Hobday et al in press.

Supporting science

These successes are possible because of

- Data handling tools – maintained by CSIRO
    - Electronic Tag Support System – tag database
    - SDODE - oceanographic data system

- Underpinning capacity and existing models
    - Satellite remote sensing
    - Bluelink Project teams (David Griffin, Richard Matear)
    - BoM's POAMA team (Oscar Alves, Debbie Hudson)

- Science and end user expertise
    - Marinelle Basson, Toby Patterson, Kirsten Rough

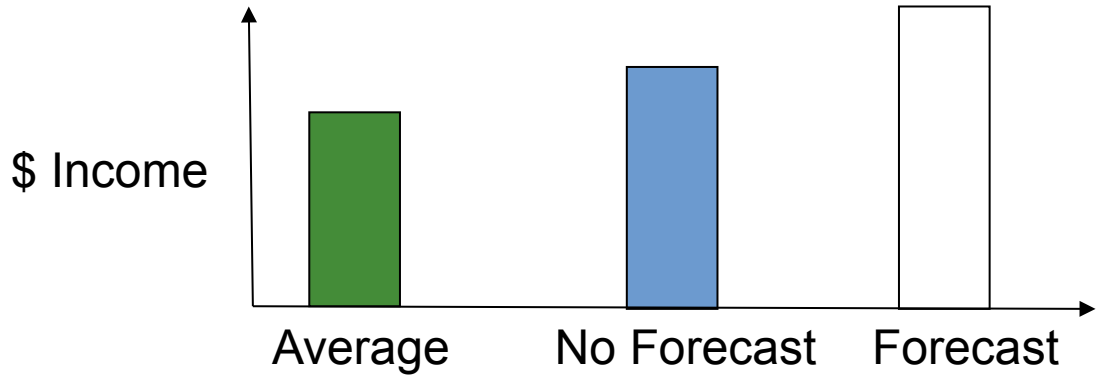
Ongoing research

- Seasonal scale
  1. More forecast applications…
     - Recreational fishers…
     - Additional variables (e.g. chlorophyll)
     - New forecasting model to replace POAMA
  2. Evaluate economic benefit of forecast use
     - Payoff times (e.g. Peter McIntosh et al)
  3. Link to risk management and capital raising
     - Little et al (2015)
  4. Downscaling forecasts for coastal applications
     - Vanhatalo et al (in review)

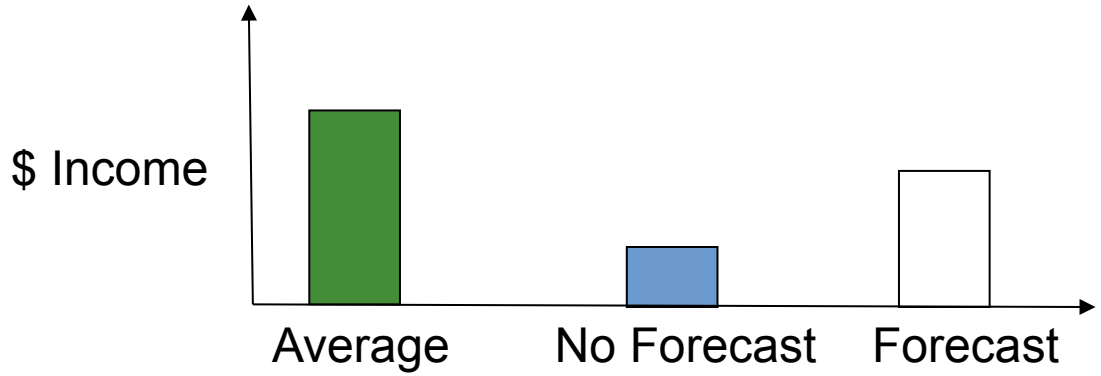
- Multi-year forecasts
  - Forecast climate drivers (e.g. ENSO, IOD, SAM) -> local conditions
    - CSIRO working group underway
    - Technical evaluation and user needs

2. Benefit of information about the future

- With forecast information - in a “good” year do better than average



- With forecast information - in a “bad” year lose less than average



3. Probalistic forecasts – pricing risk

- Can then be used to fund adaptation

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

Perspective

Funding climate adaptation strategies with climate derivatives

L. Richard Little [a,*], Alistair J. Hobday [a,1], John Parslow [a,2], Campbell R. Davies [a,3], R. Quentin Grafton [b,4]

[a] CSIRO Oceans & Atmosphere, Hobart, Tasmania 7000, Australia
[b] Crawford School of Public Policy, The Australian National University, Canberra, ACT 2601, Australia

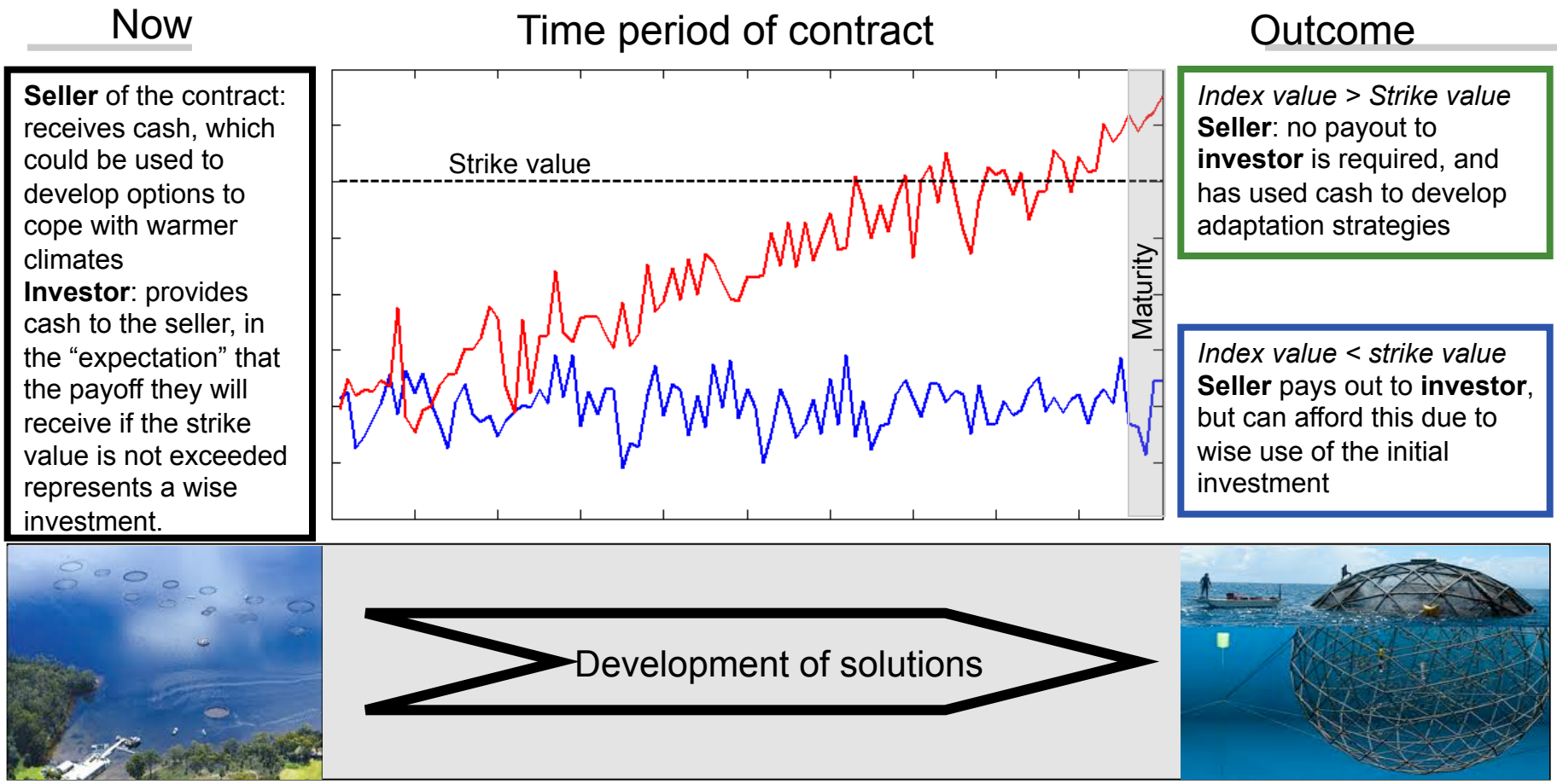
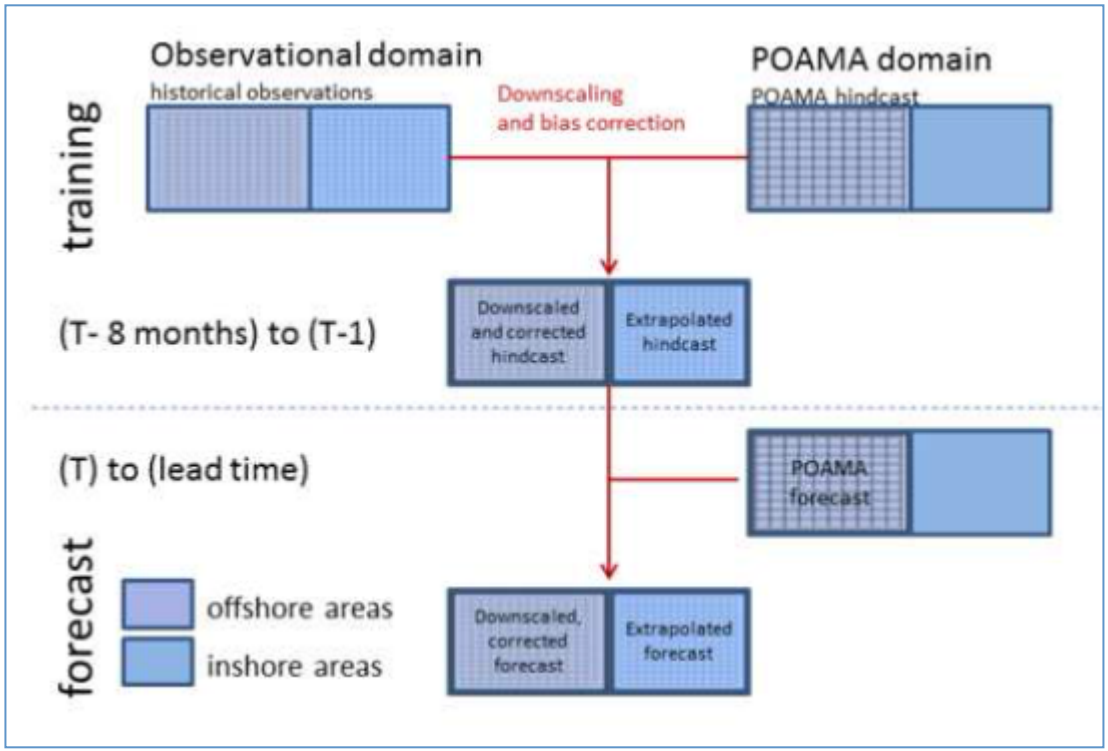


Figure 1. Derivatives and payouts. An example of an increase in temperature over the time period of the contract (red line) that would result in the strike value being exceeded at the time the derivative contract matures (grey bar), resulting in no payout from the seller to the investor. In the case that the strike price is not exceeded at the time of maturity (blue line), the seller will make a payout to the investor. In our example, the seller uses the investment to develop new salmon farming technologies to cope with anticipated effects of climate change, such as offshore farms in cooler water.

4. Downscaling and extrapolation

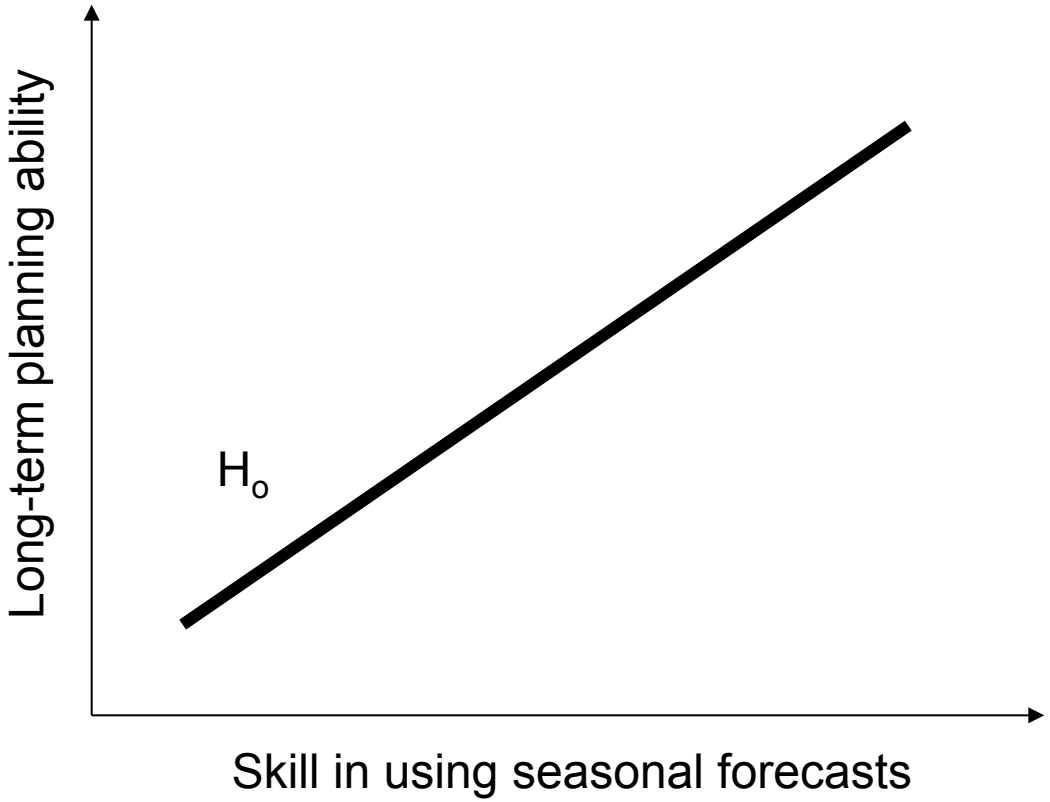
- Guassian processes with training dataset



Vanhatalo et al (in revision)

Q: Engaging at a relevant timescale….

- Does thinking more about the future lead to better long term skills?



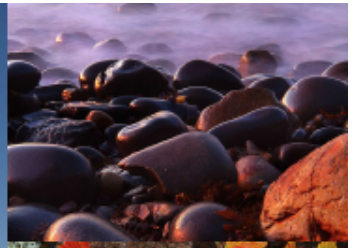
Testing planned

Further information

- Hobday and Hartmann (2006) Fisheries Management and Ecology.
- Hobday et al (2010) Fisheries Oceanography
- Hobday et al. (2011) CJFAS
- Spillman & Hobday (2014) Clim Risk Manag
- Spillman et al. (2015) Aquaculture
- Hobday et al. (2015) Fisheries Oceanography, *in press*
- Eveson et al (2015) Fisheries Research
- Little et al (2015) Climate Risk Management (Derivatives)
- Vanhatalo et al (in revision) – downscaling and extrapolation

- Forecasts: GAB: www.cmar.csiro.au/gab-forecasts
- POAMA: http://poama.bom.gov.au
  - prawns

SPECIES ON THE MOVE



DETECTION, IMPACTS, PREDICTION AND ADAPTATION.

The global redistribution of our planets' species is widely recognised as a fingerprint of climate change. However, the mechanisms that underpin such range shifts are poorly understood. Additionally, the pervasiveness of range shifts, from poles to the equator, and depths of oceans to tops of mountains, provides us with a unique opportunity to advance our theory of biogeography, evolutionary ecology and macroecology. Our move into the 'anthropocene' allows unprecedented opportunity to understand the mechanisms that drive species distributions across ecosystems and address the fundamental tenet of ecology: what lives where and why? However, such dramatic changes also pose significant challenges for sustainable management of our natural resources.

We see this conference targeting scientists and natural resource managers working in the disciplines of global change, biogeography and evolution. It will be relevant in the contexts of natural resource management, biodiversity management and conservation, and theoretical ecology. Species' responses to climate change is a rapidly evolving research field, however, much of our progress is being made in independent research areas: e.g. understanding the process vs responding to the implications, terrestrial vs marine ecosystems, global meta-analyses vs in depth species-specific approaches. This interdisciplinary conference is expected to develop connections between these parallel streams, and across temporal and spatial scales.

MORE INFORMATION

If you or your organisation/society would like to help shape this exciting conference, please contact **Dr Gretta Pecl (Gretta.Pecl@utas.edu.au)** or **Professor Stephen Williams (Stephen.Williams@jcu.edu.au)**. We would welcome suggestions for Theme Organisers, Workshops, Session Chairs and Plenary Speakers.

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